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NORWAY PINE IN THE LAKE STATES.[1]

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IMPORTANCE OF NORWAY PINE IN FOREST MANAGEMENT.

Norway pine, or red pine as it is sometimes called, is a tree whose importance is certain to increase. Even now it is important commercially. From the standpoint of forest management, however, its special value lies in the fact that it makes better growth on poor soils than does its associate, white pine; it prunes itself of branches earlier, is more hardy, is freer from injury by insects or fungi, and ranges over as wide a territory. Looking into the future, therefore, when the depletion of the present stand will make it necessary to rely upon trees that can produce merchantable timber on poor, sandy soils unsuited for agriculture, Norway pine, as its good qualities become better known, will be one of the few important trees of the Northeastern and Lake States, especially for reforestation. In past reforestation work it has often been discriminated against in favor of Scotch pine, the seed of which was easier to procure, though the tree itself had no advantages. With better methods of seed collection and storage, this drawback in the case of Norway pine can be overcome. This bulletin describes the life history of the tree, its requirements upon soil, moisture, and climate, its rate of growth and yield, and the best methods for its management.

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[1] The discussion of "Growth and Yield" and the "Appendix" are the work of Prof. Chapman.

In the main this bulletin presents the results of field work conducted under the supervision of the authors, and data collected by them through correspondence. Forest Service file data were also drawn upon, as were several unpublished reports, among them one by Mr. E. M. Griffith, State forester of Wisconsin. The manuscript was read by Mr. William T. Cox, State forester of Minnesota, and by Forest Supervisors C. E. Marshall and W. B. Piper.

Note.—The manuscript describes the life history of the Norway pine, its requirement upon soil, moisture, and climate, its rate of growth and yield, and the best methods for its management.

As this tree is already commercially important, and this importance is certain to increase, the information presented is valuable for foresters, lumbermen, and forest owners, especially as, when the present stand of timber has been depleted and dependence must rest on trees which will produce merchantable timber on poor sandy soils unsuited for agriculture, the Norway pine will be found to be one of the few important trees of the Northwestern and Lake States.

BOTANICAL AND COMMERCIAL RANGE.

Norway pine is confined to the Northeastern and Lake States and to southern Canada. Economically, it is most important in the Lake States and in Ontario. It occurs, however, as far south as southeastern Pennsylvania and as far east as Nova Scotia, Newfoundland, and eastern Maine. Its western limit is in Minnesota and its northern at the fifty-first parallel in Manitoba.

In Minnesota its commercial range extends from Lake of the Woods to the mouth of Pigeon River, and south to Lake Pepin. In Wisconsin it occurs in 27 counties, but is abundant only in the more sandy districts. In Michigan it closely follows the range of white pine.

The supply of Norway pine in the Northeastern States is now pretty well exhausted. It was heavily logged in Maine during colonial times, and has been lumbered also in Pennsylvania and New York. In Canada it is commercially important in the Provinces of Ontario and Quebec.

Figure 1 shows its botanical and commercial range.

CLIMATE, TOPOGRAPHY, AND SOIL.

In the Lake States and Ontario, where Norway pine reaches its best development, the climate is cold in Winter and rather hot and dry in summer. The annual rainfall within this region varies from 20 to 45 inches, with from 51 to 65 per cent of sunshine. In the tree's optimum range the rainfall does not exceed 36 inches, with 60 per cent of sunshine. In Wisconsin the average annual precipitation of 31.5 inches is distributed as follows: Summer, 11.2 inches; spring, 8.3 inches; autumn, 8.1 inches, and winter, 3.9 inches. Norway pine withstands a temperature of $-50°$ F. in winter and one of 105° F. in summer. In some parts of the Lake States where it grows there are frosts every month of the year. The last killing frost, however, usually occurs by May 15, and the first by September 15. The foliage of the mature tree is immune to cold, though seed production is affected. Seedlings are often damaged by periodic droughts.

Throughout its range Norway pine is forced by its associates to seek the dry, sandy, or gravelly soils. It is found on dry, coarse, sand, but produces better timber on a moderately fine, fresh sand. The tree is certainly not exacting in its soil requirements, however, since a pure, fine-grained, moderately dry sand supports some of the finest stands of Norway pine in northern Minnesota. On rich, well-drained soil the tree has great possibilities, if given the start over its competitors. In its soil and moisture requirements, Norway pine is somewhat more exacting than jack pine but considerably less so than white pine, which requires some clay in the subsoil. It can not endure drought like jack pine, but grows well on sands where the better grade of jack pine is found. Mechanical analysis has shown typical jack-pine soil to consist of 60.6 per cent coarse sand, 30.1 per cent medium sand, 3.3 per cent fine sand, and a scattering of fine gravel, very fine sand, silt, and clay. Typical Norway-pine soil is composed of 62.9 per cent fine sand, 12 per cent medium sand, 11.5 per cent very fine sand, 6.7 per cent silt, 3.7 per cent coarse sand, 2.8 per cent clay, and 0.4 per cent fine gravel. White-pine soil contains no gravel, 43.4 per cent very fine sand, 26.1 per cent silt, 16.2 per cent fine sand, 6.4 per cent clay, and 7.9 per cent coarse and medium sand. When the

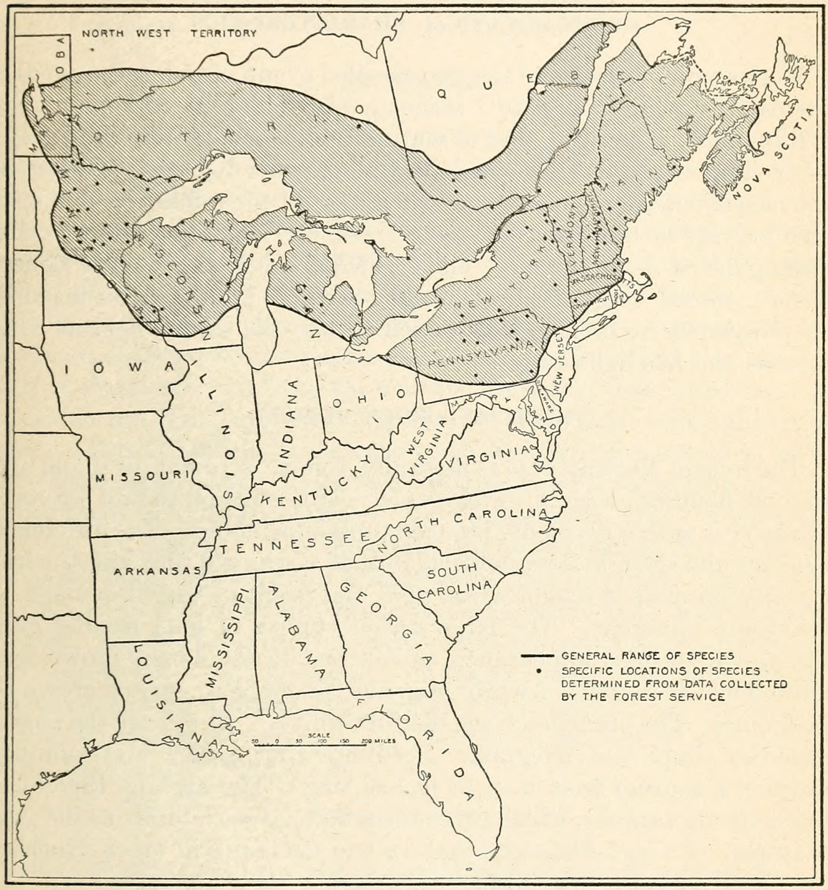

FIG. 1.—Distribution of Norway pine.

virgin stands are first cut off, these sands may grow crops for a few years until the humus is exhausted. After that the necessity for expensive fertilizers makes agriculture unprofitable except with extraordinary market conditions.

Norway pine is rarely found in hilly country or in swamps, except in Cook County, Minn., where it occurs on some high ridges. It is common along lake shores.

GROSS BOTANICAL CHARACTERISTICS.

Norway pine belongs to the two-needled group of pines, the needles themselves being from 5 to 7 inches long. The bark of young trees is thin, dark, and scaly; that of mature trees is moderately thin, grayish yellow or reddish brown, in diamond-shaped plates. Owing to the characteristic appearance of the bark and the relatively high specific gravity of the wood of young trees, the latter are often locally distinguished as "pig iron" and "shellbark Norway." The cones, some 2 inches long, are brown and brownish yellow when mature. The brownish buds have rolled-back scales; the seed is held as with forceps and has light wings.

HABIT AND ROOT SYSTEM.

The bole of Norway pine is normally slender, straight, or in old age slightly bending, with but little taper. It is unusual to find a forest-grown tree with a decidedly crooked, misshapen bole. The difference between the straight, symmetrical bole of young red pine and the frequently misshapen one of white pine, the result of weevil damage, is strikingly apparent. The large tufted clumps of long needles give the crown an open appearance, in contrast to the denser crown and more delicate needles of white pine and the ragged, narrow crown of jack pine. The branches are in distinct whorls. In old age the crown becomes short and irregular. Seedlings during the first summer develop a taproot from 6 to 18 inches long. The sapling, therefore, has a strong taproot, which gives place to to stout laterals as the tree matures. Except when overmature and declining in vigor, Norway pine is remarkably windfirm.

SIZE AND LONGEVITY.

Norway pine rarely reaches a diameter of more than 33 inches breast high. The largest tree of which there is a reliable record measured 60 inches in diameter outside the bark. On the Minnesota National Forest the average run of 16-foot logs cut from a stand mostly over 200 years old scaled 15 to the thousand board feet. The average run of mature Norway pine in mixture with hardwoods, or with white pine on the better soils, is perhaps from 11 to 13 logs to the thousand board feet. In northern Minnesota the average tree in mature timber over 200 years old measured 18.7 inches in diameter. Norway pine does not grow very tall. On the sandy soil of the region a tree from 200 to 250 years old occasionally reaches a height of from 90 to 120 feet. The tallest tree recorded was 150 feet high, but the accuracy of this measurement is questionable.

The oldest tree found was 307 years old, and but few over 280 years were encountered. Norway pine, however, seems to decline in vigor after it reaches an age of from 200 to 230 years.

TOLERANCE.

For their best development Norway pine seedlings should have direct sunlight. They can not endure as much shade as those of white pine, but will grow in a moderate shade under a jack-pine stand, and exact less light than the latter species. In small, natural openings in a Norway pine stand a few white-pine trees will seed up the ground ahead of Norway. This intolerance partly accounts for the earlier and more thorough pruning of the latter. Even in pure stands on poor soil early and clean pruning is the rule. The wind also plays a part in pruning by swaying the tall, slender-boled trees, the branches of which are thus brushed off in contact with those of neighboring trees. This is especially the case when Norway pine occurs in mixture with hardwoods. In its light requirement Norway pine may be considered as halfway between "very intolerant" and "intermediate."[1] As a means of comparison, the classification in regard to demands upon light of a few other species may be given. Balsam fir is classed as very tolerant, beech tolerant, white pine intermediate, Norway pine and red oak intolerant, and tamarack and cottonwood very intolerant. The intolerance of Norway pine is indicated by the occurrence of its reproduction; under a shade density of over 0.5 as a rule it does not reproduce. It begins to reproduce abundantly when the density falls to 0.3.

REPRODUCTION.

Norway pine seedlings need some protection against extremely hot winds and drought. On the other hand, if there is too much undergrowth or shade from the parent stand the young growth will suffer. In plantations, however, it was found that Norway pine seedlings will stand sun, exposure, and weeds much better than will those of white pine.

Norway pine produces seed in abundance only at intervals of from 3 to 5 years. The seed falls in September and early October. Seed years are local; there may be a good crop in Minnesota and a failure in Michigan or Wisconsin the same season. According to Forest Service records there have been five seed crops in Minnesota at 3-year intervals since 1898. In Wisconsin there were crops in 1890, 1893, 1897, and 1900. In Canada good seed years are said to occur not oftener than every 5 to 7 years, due possibly to the colder climate. Trees in the open have produced good cones when 25 years old, and in stands when from 50 to 60 years old. It is not known definitely when seed production begins to fail in old stands, but probably the fertility and quantity begin to fall off when the trees reach an age of 150 years. Squirrels annually destroy large quantities of seed.

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[1] For a discussion of tolerance see Forest Service Bulletin 92, "Light in Relation to Tree Growth," by Raphael Zon and H. S. Graves.

The seed is disseminated by the wind and can be relied upon to restock areas at least 300 yards away, provided the soil has been bared by logging. Even after proper dissemination there is always a chance that seed will fall on heavy litter to dry out before germination or on sodded ground where it can not get a start. Seedlings do not establish themselves after fire if there is much ash on the ground. Light burning before a seed crop may often be conducive to excellent reproduction where the soil is moderately rich. On dry, pure sand even a light fire may keep out Norway and white pine and give jack pine a start. After a fire jack pine always seeds before Norway, because it produces seed each year, which are released from cones by the heat of the fire. White pine will come in first where there is partial shade, provided it is not crowded out by broadleaf trees. On areas between these two extremes of baked, parched soil, free from all growth on the one hand and ground covered with dense underbrush on the other, Norway pine reproduction will have the best chance.

However, the three pines compete with one another for the occupancy of the ground, as shown by actual measurements of reproduction on small plots in the National Forests. On the Minnesota National Forest, on an area where 5 per cent of the stand had been reserved for seed, there were 1,900 Norway and white pine seedlings per acre which had come in on exposed mineral soil rather than near the seed trees. In Hubbard County, Minn., on a plot 50 by 100 feet, there are 499 jack pine seedlings and only 481 of Norway pine, although there were two Norway pine seed trees and no jack pine within 300 feet. In a small, open stand, composed of 3 white pine and 70 Norway pine, growing on sandy soil, there were 13 white pine seedlings to every 1 of Norway pine. Near Mahtowa, Minn., young stands of Norway pine 7 and 8 years old averaged 20,855 trees to the acre, and near Barnum and Moose Lake stands about 23 years old averaged 4,699 trees to the acre. This shows that excellent reproduction of Norway pine is possible, provided soil conditions during the seed year are favorable, notwithstanding the fact that the tree is a meager seed bearer. Reproduction on the average cut-over tract is usually very deficient because of fire and excessive cutting. Aspen, paper birch, and jack pine usually crowd out the white and Norway pine. On most cut-over lands there are few Norway pine seed trees, so that reseeding will take centuries unless assisted by artificial reforestation.

SUSCEPTIBILITY TO INJURY.

Freedom from ordinary injuries constitutes the strongest recommendation in favor of Norway pine for forest management. This quality might adapt the tree to turpentining, though the short growing season would be a decided drawback.

FIRE.

Mature Norway pine may be charred at the butt by an ordinary ground fire, especially the uphill side of the tree where there is an accumulation of needles, but the burn is seldom followed by decay. Careful observations in northern Minnesota[1] indicate that young Norway pine seedlings resist fire better than either white or jack pine.

OTHER DAMAGE.

Norway has few serious enemies. In the seedling stage it seems to suffer no more from damping off than do other conifers, though the tender roots are occasionally attached by a grub as yet unidentified. It is rarely frost killed, but in the forest a prolonged drought may seriously decrease the seed crop. In the sapling and pole stage it is practically free from windfall and fungi. Mature Norway pines, when growing on well-drained soil, are rarely defective. The strong lateral root system makes the tree windfirm, though if isolated when overmature it may blow down.

THE WOOD.[2]

APPEARANCE AND STRUCTURE.

The wood of Norway pine is redder in color, in most cases slightly heavier, and invariably more resinous than that of other northeastern commercial conifers. However, before seasoning, the softer grades, cut from trees of rapid growth, are scarcely distinguishable from those of white pine. After thorough seasoning this similarity is less marked, because Norway pine is generally darker and more resinous.

The better quality Norway pine wood is soft, light, moderately strong and tough, fine, and straight grained. It is easy to work, but is not durable in contact with the soil. The best grades are cut from trees of rapid growth, on low, moist, rich soil, and exhibit very little contrast between early and late growth. Lumber cut from slow-growing trees, on dry, sandy soils, is redder in color, more resinous, and somewhat harder and more durable than the other. There is also a marked difference between the weight and quality of lumber cut from young stands and from mature timber, due to the percentage of sapwood in the former. Sargent gives the specific gravity of dry wood (unquestionably cut from mature trees) as 0.485. The sapwood of immature trees has a specific gravity of 0.9, and the heartwood of 0.6. It is this difference between sapwood and heartwood which perhaps gives rise to the term "pigiron," since second-growth Norway pine with a wide sapwood would not float. In the course of experiments by the Forest Service, under the direction of H. D. Tiemann, small blocks cut from "pigiron" floated from 2 to 9 days, while heartwood floated from 3 months to 1 year. Thus the floating ability of timber cut from young stands can be determined by computing the volume per cent of sapwood and heartwood in the logs. In mature trees the sapwood is narrow, rarely exceeding 3 inches.

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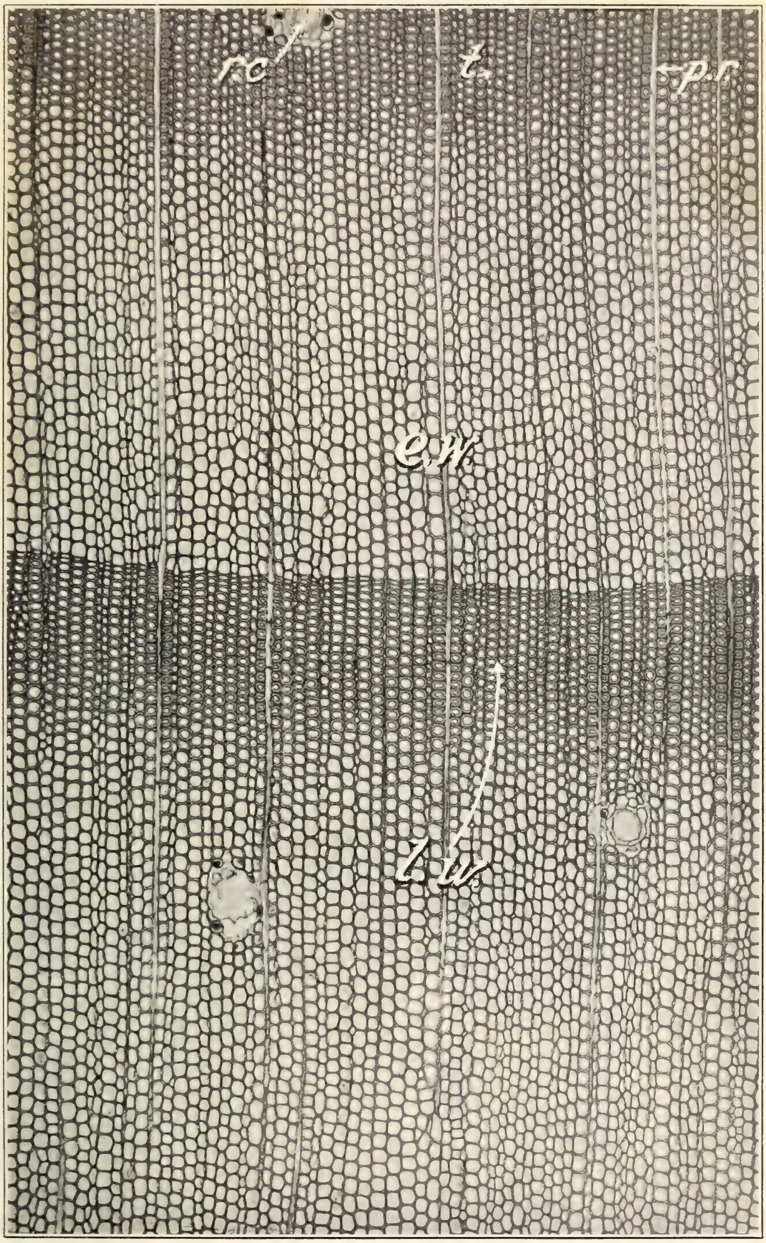
[1] "Report on the Jack Pine Barrens of Northern Minnesota," by J. P. Wentling.

[2] Prepared by C. D. Mell, assistant dendrologist, and W. D. Brush, scientific assistant, Forest Service.

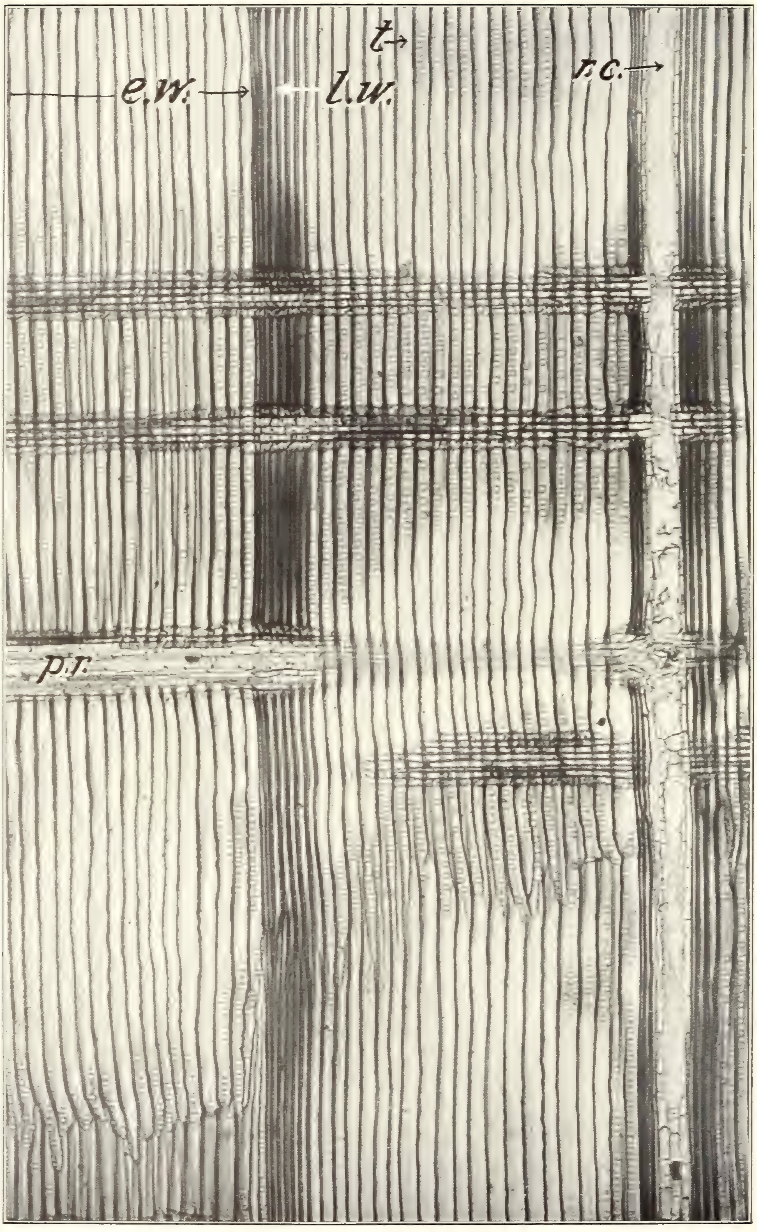
In the softer grades of Norway pine the late wood of the annual rings does not contrast very sharply with the early wood, as is the case with the hard grades, or in the yellow or hard pines, of which longleaf pine is typical. Moreover, the late wood usually forms much less than one-half of the width of the annual ring. This and the slight contrast between the inner and outer part of the annual ring gives the wood a rather uniform structure and density, rendering it equal to white pine for many purposes.

Microscopic characters which distinguish Norway pine from other pine woods with which it is likely to be confused are the conspicuous dentate projections on the inner walls of pith-ray tracheids and the large simple pits (from 1 to 2) to each longitudinal tracheid and the radial walls of the ray-parenchyma cells. The following analytical key will be of assistance to technical students in the identification of red, white, and jack pine:

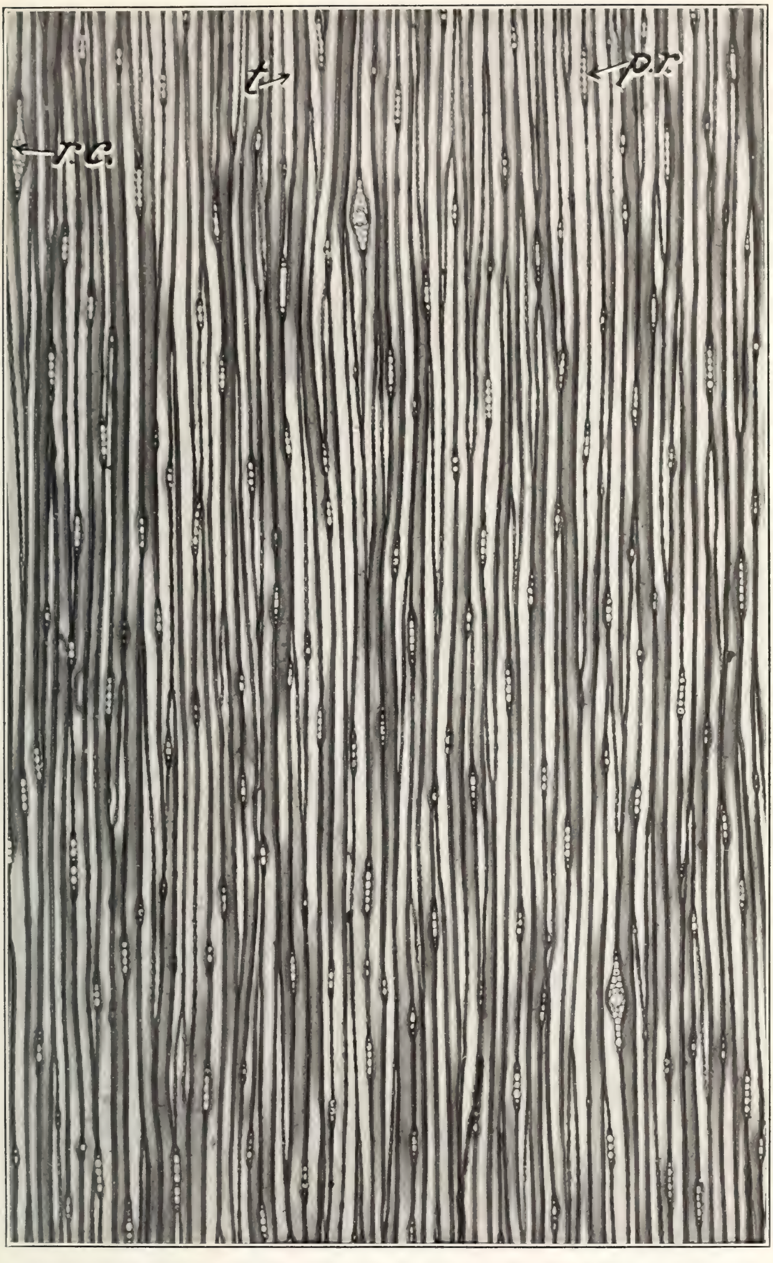
Inner walls of pith-ray tracheids without dentate projections.
  One to 2 large simple pits to each longitudinal tracheid on the radial walls of the ray-parenchyma cells. Late wood narrow, inconspicuous; wood sparingly resinuous.......................................White pine (*Pinus strobus*)
Inner walls of pith-ray tracheids with conspicuous dentate projections.
  One to 2 large simple pits to each longitudinal tracheid on the radial walls of the ray-parenchyma cells. Dentate projections regular, short. Late wood conspicuous, not sharply defined from the lighter early wood of the same annual ring. Wood usually very resinous..............Norway pine (*Pinus resinosa*)
  One to 6 (usually 3 to 6) oval, simple pits to each longitudinal tracheid on the radial walls. Dentate projections irregular, long, often branched and connecting across the cells. Late wood very conspicuous, sharply defined from the early wood. Wood moderately resinous......Jack pine (*Pinus divaricata*)



TRANSVERSE SECTION OF THE WOOD OF NORWAY PINE MAGNIFIED 50 DIAMETERS; *e. w.*, EARLY WOOD; *l. w.*, LATE WOOD; *t.*, TRACHEIDS; *p. r.*, PITH RAY; *r. c.*, RESIN CANAL.



RADIAL SECTION OF THE WOOD OF NORWAY PINE MAGNIFIED 50 DIAMETERS; *e. w.*, EARLY WOOD; *l. w.*, LATE WOOD; *t.*, TRACHEIDS; *p. r.*, PITH RAY; *r. c.*, RESIN CANAL IN PITH RAY; ALSO A LONGITUDINAL CANAL.



TANGENTIAL SECTION OF THE WOOD OF NORWAY PINE MAGNIFIED 50 DIAMETERS; *t.*, TRACHEIDS; *p. r.*, PITH RAYS; *r. c.*, RESIN CANAL IN PITH RAY.

STRENGTH.

Norway pine is stronger than white pine, but weaker than longleaf. Grade for grade, it is not quite as strong as tamarack, but experiments by the Forest Service showed thoroughly seasoned Norway pine to be slightly stronger and stiffer, when the seasoning checks in tamarack were considered. The results of the strength tests are given in Table 1.

TABLE 1.—*Strength of green Norway pine in bending, compression, and shear.*

Section.	Span.		Number of tests.	Rings.	Moisture.	Weight per cubic foot.		Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Modulus of resilience.	Shearing stress at rupture.
						As tested.	Dry.					
MAIN BENDING TESTS.												
				Per inch.	*Per cent.*	*Pounds.*	*Pounds.*	*Lbs. per sq. in.*	*Lbs. per sq. in.*	*1,000 lbs. per sq. in.*	*Inch=lbs. per cu. in.*	*Lbs. per sq. in.*
4 by 10 inches	13 feet 6 inches	Average	49	13.6	[1] 43.8	[1] 36.3	[1] 25.2	2,550	3,975	1,189	0.52	
4 by 12 inches		Maximum		32.4				3,915	5,625	1,700	1.03	
6 by 12 inches		Minimum		6.7				1,600	2,810	808	.22	
MINOR BENDING TESTS.												
2 by 2 inches	30 inches	Average	135	11.4	[1] 33.3	[1] 34.6	[1] 26.0	2,808	5,173	960	0.48	
		Maximum		32.0				5,100	7,610	1,578	1.49	
		Minimum		4.0				1,420	3,070	495	.18	
COMPRESSION TESTS—LARGE PIECES.[2]												
4 by 7 inches and 6 by 7 inches		Average	13	10.7	[1] 45.6	[1] 31.8	[1] 21.9	2,090	2,560	1,024		
		Maximum		16.7				2,725	3,180	1,375		
		Minimum		6.2				1,555	2,020	722		
COMPRESSION TESTS—SMALL PIECES.[3]												
2 by 2 inches		Average	178	11.4	Green.				2,504			
		Maximum		32.0					4,740			
		Minimum		4.0					1,400			
SHEARING TESTS—SMALL PIECES.												
1 by 4 inches and 2 by 4 inches		Average	20	7.5	Green.							589
		Maximum		15.0								768
		Minimum		5.0								476

[1] Moisture determinations not completed for all tests.

[2] Height of specimen, 30 inches.

[3] Height of specimen, 8 inches.

PRESERVATIVE TREATMENT.

Since Norway pine is not durable in contact with the ground and when exposed to moisture, timber so placed must be treated with some preservative. The details of various methods of preservation are discussed in Forest Service Bulletins 78, 84, and 118; Circulars 80, 98, 101, 104, 111, 112, 117, 128, 132, 134, 136, 139, and 151; and Department Bulletin 13.

FOREST TYPES.

Only on moderately poor soils, usually a sand, does Norway pine grow pure. On the richer soils and on well-watered sandy flats it is found in mixture with hardwoods and white pine, and on the driest sands with jack pine. In Ontario the densest stands of Norway pine are found on pure-sand plains. Four chief types may be distinguished: (1) Norway pine knoll; (2) Norway pine flat;[1] (3) hardwood ridges; and (4) jack-pine plains.

NORWAY PINE KNOLL.

The pure sand of the knolls favors Norway pine, which is the chief, or perhaps the only, tree on such situations. The soil cover is a scattering of wintergreen, blueberry, and ''ground pine,'' with a thin mat of needles.

NORWAY PINE FLAT.

On the sandy flats Norway pine may occasionally grow pure, but where clay is present in the soil white pine forms from 40 to 60 per cent of the stand, with a much denser ground cover. Clumps of birch may occupy the openings. On low, poorly drained ground there is usually a scattering of white spruce and occasionally a tamarack. The moist soil insures dense undergrowth.

HARDWOOD RIDGES.

On the glacial ridges, where a drift of clay covers the subsoil, the forest is chiefly broad leaved. Aspen, sugar maple, hornbeam, paper birch, yellow birch, basswood, black ash, white ash, mountain maple, with a scattering of white spruce, white pine, and Norway pine, form the stand. Often there is a pure growth of aspen, with a few paper birch, white spruce, and maple. Again, paper birch is pure with a few aspens, hornbeams, or spruces. In certain localities there is ample evidence that much of this hardwood land bore white pine of enormous size. Fire and windfall probably caused the change in the type. Often a few overmature white and Norway pines rise out of the dense understory of hardwoods. Some of the largest Norway pines are found scattered through hardwood forests. They have broad, bushy crowns, with a comparatively short, very full, well-pruned bole.

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[1] On the richer soils this type would be locally termed white pine flat.

JACK-PINE PLAINS.

Jack pine obtains possession of the driest, sterile sands through its ability to reproduce prolifically after fire and to grow rapidly during the seedling and sapling stages. Originally, it is believed, Norway pine formed at least 10 per cent of the stand on this type, but repeated fires have decreased this proportion until on some sand plains there is no Norway pine at all.

COMPETITION WITH OTHER SPECIES.

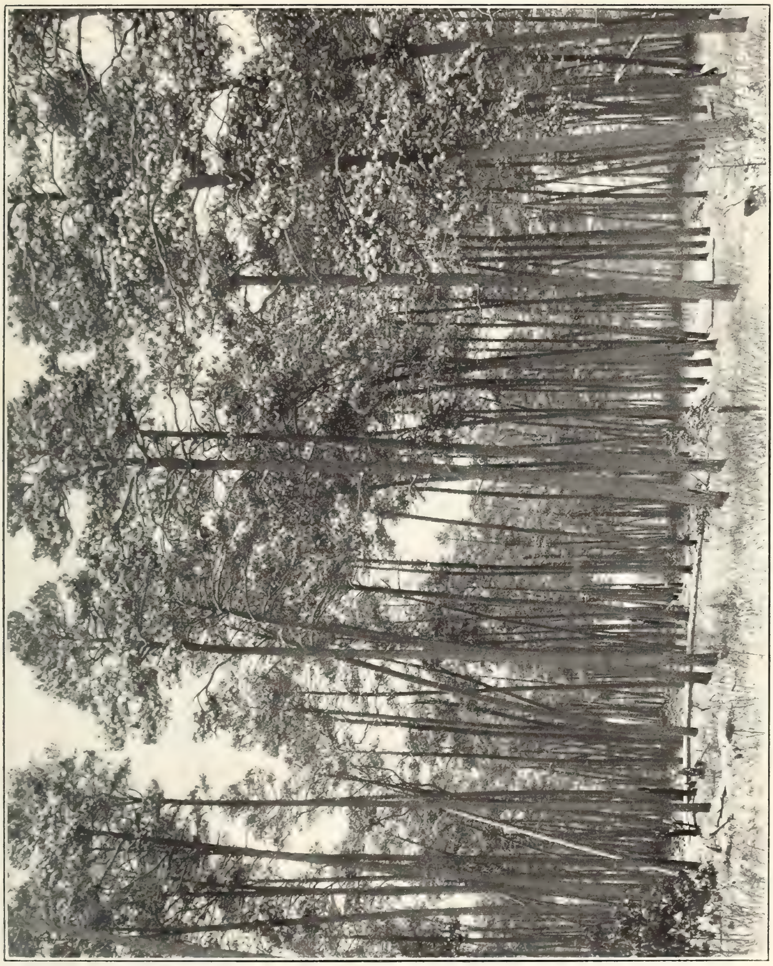
For Norway pine to succeed, the ground must be at least partially free from thick grass, briars, and weeds and not excessively dry. White pine, on the other hand, succeeds best with some cover, such as bushes, berry vines, or scattered poplar and cherry seedlings. On the richer soils the tolerance of white pine enables it to obtain a start over Norway, which is usually crowded out. On moderately dry, pure sand Norway pine drives out the white pine and hardwoods by its more rapid growth. On rich clay, suitable for agriculture, the hardwoods obtain the supremacy through their ability to seed up the soil and get a good start. As such stands become open, however, white pine, and later some Norway pine, gain a foothold. Dry, coarse sands favor jack pine, which grows faster than Norway pine at the start, but which begins to decline in vigor when from 80 to 90 years old, permitting the Norway pine to break through the crown cover and quickly occupy the available growing space.

SUPPLY AND CUT.

The total stand of all pines in the Lake States to-day probably amounts to more than 50,000,000,000 board feet. Of the 250,000,000,000 feet estimated to have been cut in the Lake States since lumbering began, Norway pine has probably furnished about 15 per cent, or about 37,000,000,000 board feet. The estimated present stand of Norway pine—17,000,000,000 feet—will probably appear too small after another decade or so, since with proper fire protection the production of second growth should materially increase the supply.

Accurate estimates of the cut of either white or Norway pine in the Lake States are impossible, because the two species are marketed together. Mr. R. S. Kellogg, secretary of the Northern Hemlock and Hardwood Manufacturers' Association, has estimated that between 1880 and 1910 Norway pine formed 25 per cent of the total cut in Michigan, 20 per cent of that in Wisconsin, and 15 per cent of that in Minnesota. These figures may be taken as conservative. In 1911, Mr. H. S. Childs, secretary of the Northern Pine Manufacturers' Association, estimated that Norway pine cut 30.4 per cent of the total production in Minnesota and Wisconsin, a conclusion reached on the

PLATE IV.



CLOSE STAND OF NORWAY PINE, CASS LAKE, CASS COUNTY, MINN.

basis of a census of 17 manufacturers in the former State and 12 in the latter. The proportion of Norway pine to the total cut of former years was no doubt small, but it has probably always formed from 10 to 20 per cent. In 1906, H. H. Chapman, professor of forestry at the Yale Forest School, wrote:

> The proportion of Norway pine in the total annual cut in Wisconsin is rapidly increasing lately at the expense of white pine, and is now about 33 per cent of the annual cut of pine for the State, excluding hemlock, while in the Wisconsin Valley the proportion reaches nearly 50 per cent. In past years Norway pine formed only from 5 to 10 per cent of the Wisconsin pine cut. In Minnesota Norway pine forms 30 per cent of the pine cut.

A further cause for uncertainty with regard to the cut of Norway pine has been introduced by the increasing cut of jack pine, some of which is being marketed as "Norway."

GRADES.

Norway pine is graded under rules agreed upon by the Northern Pine Manufacturers' Association. These are given in Table 2. The details of each grade are discussed in a booklet of rules which can be obtained upon request from the secretary of the association.

TABLE 2.—*Standard grades of Norway pine.*

- Thick finishing:
  - 1st, 2d, and 3d clear, 1¼, 1½, and 2 inch.
  - A select, 1¼, 1½, and 2 inch.
  - B select, 1¼, 1½, and 2 inch.
  - C select, 1¼, 1½, and 2 inch.
  - D select, 1¼, 1½, and 2 inch.
- Inch finishing:
  - 1st, 2d, and 3d clear.
  - A, B, C, and D select.
  - D stock.
  - C and better Norway.
- Siding:
  - A and clear.
  - B, C, D, and E.
- Flooring:
  - A, B, C, and D flooring.
  - Farmer's clear flooring.
  - No. 1, No. 2, and No. 3 fencing, D. and M.
- Shiplap, grooved roofing, and D. and M.:
  - No. 1, No. 2, and No. 3.
- Factory plank or shop common:
  - No. 1, No. 2, and No. 3 shop.
  - Inch shop.
  - Short box.
- Factory selects:
  - Factory A select and better.
  - Factory B and factory C select.
- Thick common lumber:
  - Tank stock.
  - Select common.
  - No. 1, No. 2, No. 3, No. 4, and No. 5 common.
- Common boards:
  - No. 1, No. 2, No. 3, No. 4, and No. 5.
- Fencing:
  - No. 1, No. 2, No. 3, and No. 4.
- Dimension:
  - No. 1, No. 2, and No. 3 or cull.
- Lath:
  - No. 1 and No. 2.

PRICES.

Norway pine has risen greatly in value during the past two decades. Virgin Norway was once purchased for less than 50 cents per thousand board feet. To-day values less than $4 per thousand board feet for good "second growth" are exceptional. Stumpage on the National Forests in Michigan is sold for as much as $12 per thousand, and will undoubtedly go still higher.

The better grades of Norway pine, when sold as such, bring less in the open market than do similar grades of white pine, but below the No. 1 grade in dimension or No. 2 in inch lumber the two species bring the same. Norway pine is seldom, if ever, quoted separately in lumber price lists. Even in high grades it is often sold indiscriminately with white pine, and so brings the same price. As a general rule, therefore, the prices quoted for white pine can be taken as those for Norway as well. Average mill-run prices for white pine in Minnesota and Wisconsin during the last quarter of 1913 were as follows:

Selects C and better	$56.00
Shop, No. 1, 8/4	48.49
Shop, No. 3, 5/4	22.87
Bevel side	24.42
Timber, No. 1, 2 inches by 4 inches by 16 feet	20.33
Boards:	
No. 2	22.83
No. 3	21.00
No. 4	16.66
Fencing, No. 2	25.36

MARKETS.

With the decrease in the supply of white pine lumber, Norway pine is certain to come more and more into demand. A glance at the list of uses given below for which Norway pine is adapted shows its commercial possibilities. In the investigation of the Wisconsin wood-using industries the Forest Service found that approximately 7,500,000 feet of Norway pine, valued at $124,000, was annually used in that State alone, of which 84 per cent was logged within the State. A similar study in Minnesota showed an annual consumption in that State of over two and one-half million dollars worth of Norway pine, costing on the average $15.74 per thousand board feet.

USES.

Norway pine is adapted for most of the uses to which white pine is put. It was first cut in Maine and Canada for shipbuilding material, such as decking, planking, spars, and masts.[1] It is used locally for bridges, though it is distinctly inferior to longleaf pine and Douglas fir for the purpose. Perhaps it is in widest demand for dimension stuff and for ordinary house construction. The lower grades and smaller sizes are consumed largely by the box trade for crates and shipping boxes, and less frequently for shingles and water pipes. The better grades are used for farm implements, planing-mill products, furniture, car construction, panels, screens, doors and sash, and when treated with preservatives for poles, posts, and ties. The Chicago & North Western Railway is authority for the statement that Norway pine piling, where below the water and moisture line, gives excellent service, since the wood does not splinter badly under ordinary driving. During 1911 and 1912 over 20,000 pieces of piling, from 40 to 64 feet long, were sold on the Minnesota Forest at from $16 to $20 on the stump. When used for bridge piling above ground the sapwood rots quickly unless treated. Norway pine paving blocks, impregnated with 16 pounds of oil per cubic foot have given excellent results in Minneapolis.[1] While experiments with the paving blocks are still in progress, it has already been established that Norway pine, though slightly inferior to longleaf pine, is fully equal to western larch and white birch as a paving material. There is no positive record of the wood's value for pulp. The stumps yield turpentine, and are a satisfactory raw material for distillation. Other parts of the tree are not considered sufficiently resinous for the purpose.[2] A company in Michigan reports a yield of 8 gallons of turpentine and 270 pounds grade F rosin per cord of 4,000 pounds of stump wood. In Wisconsin about 61 per cent of the local output and importations of Norway pine are used for boxes and 23 per cent for sash, doors, blinds, and interior and exterior finish. In Michigan about 42 per cent goes into planing-mill supplies, and 24 per cent into boxes and crates. In Minnesota the most important uses of Norway pine are for gates and fencing, and for paving.

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[1] For further details regarding early uses of Norway pine, see Forest Service Bulletin 99, "Uses of Commercial Woods in the United States: Pines," by Hu Maxwell and William L. Hall.

GROWTH AND YIELD.

HEIGHT GROWTH.

Norway pine makes an average height growth of 1 foot per year until it reaches an age between 60 and 70 years. From that time on the height growth gradually falls off, until at the age of from 100 to 110 years it practically ceases. The crown of the tree then assumes a broad flat shape.

When planted together with white pine, the height growth of Norway exceeds that of the former for the first few years by from 3 to 5 feet. This initial advantage soon disappears, however, since the white pine maintains its height growth to a greater age. Jack pine grows much faster than either Norway or white pine for the first two decades, a characteristic which in many instances enables it to over-top and partially or completely suppress the other pines. The height growth of Norway pine is best in full sunlight, when slightly crowded.

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[1] For more detailed information, see Forest Service Circular 194, "Progress Report on Wood Paving Experiments in Minneapolis," also Municipal Engineering, Vol. XXXIV, p. 14.

[2] For further information see Forest Service Circular 114, "Wood Distillation."

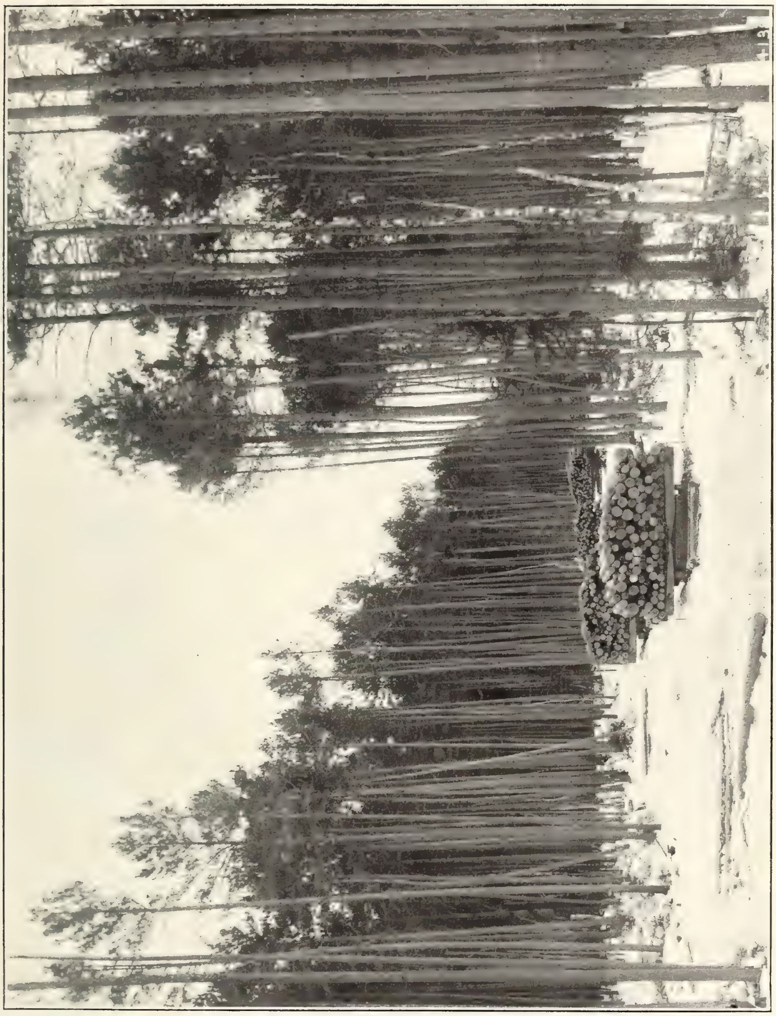
The average height growth of saplings in fairly well-stocked stands is shown in Table 3. No measurements were made of the growth in height of older trees. From the measurements of height on diameter, Table 4, and the measurements of diameter on age, Table 7, it was possible to construct a table of height growth based on age. This table is based on the assumption that diameter and height growth are roughly proportional. Thus, if the height of a tree of a given diameter is known and also the age of the diameter corresponding to the height of this tree, the age of the tree having this height is thereby determined. Table 5 has been constructed after this plan. It shows the average height of trees of different ages. Figures for minimum and maximum heights are also given. The maximum trees grew in Wisconsin in mixture with white pine and were dominant. The minimum figures are for slow-growing suppressed trees.

TABLE 3.—*Height growth of saplings in northern Minnesota.*

Age (years).	Height.	Age (years).	Height.	Age (years).	Height.	Age (years).	Height.
	Feet.		*Feet.*		*Feet.*		*Feet.*
1	0.3	8	4.9	15	15.0	22	23.0
2	.6	9	6.0	16	16.7	23	23.8
3	1.0	10	7.2	17	18.1	24	24.6
4	1.5	11	8.5	18	19.3	25	25.5
5	2.2	12	9.9	19	20.4	26	26.3
6	2.9	13	11.4	20	21.3	27	27.1
7	3.9	14	13.1	21	22.1	28	28.0

TABLE 4.—*Minimum, average, and maximum heights based on diameter, Minnesota and Wisconsin.*

Diameter breast-high (inches).	Height.			Diameter breast-high (inches).	Height.		
	Minimum.	Average.	Maximum.		Minimum.	Average.	Maximum.
	Feet.	*Feet.*	*Feet.*		*Feet.*	*Feet.*	*Feet.*
1	11	12	16	18	61	88	112
2	16	20	28	19	63	90	113
3	18	27	41	20	66	91	114
4	21	34	52	21	68	92	115
5	24	41	63	22	71	94	116
6	26	47	72	23	73	95	116
7	29	53	80	24	76	96	117
8	32	58	87	25	78	97	118
9	35	63	93	26	80	99	119
10	38	67	97	27	83	100	120
11	41	71	101	28	85	101	121
12	44	74	103	29	87	103	122
13	47	77	105	30	89	104	123
14	50	80	107	31	91	105	124
15	53	82	108	32	93	106	125
16	55	85	109	33	95	108	126
17	57	87	110	34	98	109	127



FOREST OF NORWAY PINE, WITH LOADED SLEDS ON ICE ROAD, RED LAKE COUNTY, MINN.

Table 5.—*Minimum, average, and maximum heights based on age, Bayfield County, Wis.*

Age (years).	Height.			Age (years).	Height.		
	Minimum.	Average.	Maximum.		Minimum.	Average.	Maximum.
	Feet.	*Feet.*	*Feet.*		*Feet.*	*Feet.*	*Feet.*
10	7	12	19	110	74	92	102
20	16	35	56	120	78	94	104
30	26	58	78	130	81	95	105
40	34	70	86	140	83	96	107
50	43	77	91	150	86	98	108
60	50	82	94	160	88	99	109
70	56	85	96	170	89	100	110
80	62	88	98	180	91	101	
90	67	90	99	190	93	103	
100	71	91	101	200	94	104	

Table 5 apparently indicates that the height growth of maximum trees is very rapid for 40 years and soon afterwards dwindles to almost nothing. In reality the height growth is much more gradual and continues longer than indicated in the column headed "Maximum." The most rapidly growing trees, which apparently show a height of 86 feet for 40 years, are merely trees which when 86 feet high have a diameter of 13.8 inches, this being the average height of a tree of that diameter. As a matter of fact, a tree which grew 13.8 inches in diameter in 40 years could not reach a height of 86 feet in the same time. The column containing the average figures gives a more nearly correct idea of the growth in height.

Table 4 shows the relation between diameter and height.

DIAMETER GROWTH.

The diameter growth of a tree is influenced to a very marked extent by the quality of the soil and the density of the stand. This effect is clearly shown in the following classes: (1) Dominant trees. According to their past history in the stand these may be divided into those which have survived to reach merchantable size, those which occupy a dominant position in the stand, and those which have been suppressed for about 100 years by jack pine; (2) intermediate trees; and (3) suppressed trees. The growth in diameter of these different classes of trees, with different crown development, is shown in Tables 6 to 10. Table 6 gives the best, average, and slowest growth in diameter on good soil in Bayfield County, Wis., for trees which survived to reach merchantable size.

TABLE 6.—*Minimum, average, and maximum growth in diameter, Bayfield County, Wis., on basis of age.*

[Based on 139 stumps from 108 to 202 years old.]

Age (years).	Diameter breast-high (inches).			Age (years).	Diameter breast-high (inches).		
	Minimum.	Average.	Maximum.		Minimum.	Average.	Maximum.
10	0.2	0.6	1.3	110	9.3	17.9	25.2
20	1.0	2.8	5.4	120	10.3	18.9	26.2
30	1.9	5.7	10.3	130	11.3	19.8	27.1
40	2.7	8.0	13.8	140	12.4	20.8	28.0
50	3.7	9.9	16.6	150	13.5	21.7	28.7
60	4.6	11.7	18.8	160	14.6	22.7	29.5
70	5.5	13.2	20.5	170	15.7	23.7	30.3
80	6.5	14.6	21.9	180	16.9	24.6	30.9
90	7.4	15.9	23.1	190	18.0	25.5	31.7
100	8.3	16.9	24.2	200	19.2	26.5	32.4

Table 7 shows the diameter growth of trees which are now occupying a dominant position in the stand. Figures in the column headed "Maximum" are for trees which have grown practically in the open for their entire life. The column headed "Average" shows trees which have been somewhat crowded, but which from the start have dominated the remaining timber in height growth. The "minimum" is for trees which have been suppressed by jack pine. The growth in both diameter and height of such Norway pines is stunted. In 80 years the trees have reached a diameter of but 4.3 inches, as contrasted with 19.2 inches in the case of open-grown trees. At this age jack pine dies out, and by 100 years has entirely disappeared from these even-aged stands. The surviving Norway pines, freed from competition and with plenty of crown space, develop good crowns and take the position of intermediate or dominant trees. Only their record of diameter growth remains to show the former existence of the jack pine in mixture. Had these trees grown in pure stands, they would have been killed in competition.

TABLE 7.—*Minimum, average, and maximum diameter growth of dominant trees on basis of age, Cass and Itasca Counties, Minn.*

[Based on 739 stumps from 27 to 303 years old.]

Age (years).	Diameter breast-high (inches).			Age (years).	Diameter breast-high (inches).		
	Minimum.	Average.	Maximum.		Minimum.	Average.	Maximum.
10	....	0.8	2.7	110	6.8	14.7	22.1
20	0.4	2.8	6.8	120	7.6	15.5	22.8
30	.8	4.9	10.1	130	8.4	16.1	23.5
40	1.3	6.6	12.6	140	9.1	16.7	24.1
50	2.0	8.2	14.6	150	9.8	17.3	24.7
60	2.7	9.6	16.4	160	10.4	17.8	25.2
70	3.5	10.9	17.9	170	10.9	18.4	25.7
80	4.3	12.0	19.2	180	11.3	18.9	26.3
90	5.2	13.0	20.3	190	11.8	19.5	26.7
100	6.0	13.9	21.3	200	12.1	20.0	27.2

Table 8 shows the diameter growth of intermediate trees on situations typical of the sandy plains of low agricultural value.

TABLE 8.—*Minimum, average, and maximum diameter growth of intermediate trees on the basis of age, Cass and Itasca Counties, Minn.*

[Based on 760 stump counts.]

Age (years).	Diameter breast-high (inches).			Age (years).	Diameter breast-high (inches).		
	Minimum.	Average.	Maximum.		Minimum.	Average.	Maximum.
10	0.4	0.9	2.3	110	6.6	13.5	21.7
20	.9	2.7	6.0	120	7.2	14.2	22.5
30	1.4	4.6	9.3	130	7.7	14.9	23.1
40	2.0	6.3	12.0	140	8.2	15.5	23.6
50	2.6	7.8	14.2	150	8.7	16.1	24.1
60	3.3	9.1	16.0	160	9.1	16.7	24.6
70	3.9	10.3	17.5	170	9.5	17.2	25.0
80	4.6	11.3	18.9	180	9.9	17.7	25.4
90	5.3	12.1	20.0	190	10.3	18.3	25.7
100	5.9	12.9	20.9	200	10.7	18.9	26.0

Table 9 shows the growth of suppressed trees.

TABLE 9.—*Minimum, average, and maximum diameter growth of suppressed trees on basis of age, Cass and Itasca Counties, Minn.*

[Based on 164 stumps, 51 to 152 years old.]

Age (years).	Diameter breast-high (inches).			Age (years).	Diameter breast-high (inches).		
	Minimum.	Average.	Maximum.		Minimum.	Average.	Maximum.
10	....	0.5	1.3	90	5.3	9.5	14.8
20	0.5	1.8	3.9	100	6.0	10.1	15.5
30	1.1	3.2	6.4	110	6.7	10.7	16.1
40	1.7	4.5	8.7	120	7.2	11.3	16.8
50	2.4	5.8	10.6	130	7.7	11.8	17.4
60	3.1	7.0	12.0	140	8.1	12.3	18.0
70	3.9	8.0	13.1	150	8.5	12.8	18.6
80	4.6	8.8	13.9				

The demand of Norway pine for light, which prevents it from growing under hardwoods, white pine, or underbrush, is brought out in the growth tables. When growing with any other species except jack pine it must remain dominant by means of rapid growth or be killed by suppression in the course of time. Jack pine has such a light crown that in mixture with it Norway pine can survive a period of extended suppression and ultimately develop a fair crown growth. The better the soil the closer will be the competition between these two species. On very poor soils Norway pine in mixture with jack pine sometimes lives to an advanced age as mere stunted poles from 10 to 20 feet high and from 1 to 8 inches in diameter.

VOLUME GROWTH.

Growth in volume of Norway pine (Table 10) is derived from tables of growth in diameter and height at different ages, used in connection with a table in volumes for trees of different diameters and heights. The table indicates that Norway pine grows in volume at a uniform rate to an advanced age.

TABLE 10.—*Growth in volume, on basis of age, of average dominant trees, Cass County, Minn.*

Age (years).	Diameter.	Height.	Volume.	Scribner rule.	Periodic growth for 10-year periods.		Mean annual growth.	
	Inches.	*Feet.*	*Cubic feet.*	*Board feet.*	*Cubic feet.*	*Board feet.*	*Cubic feet.*	*Board feet.*
10	0.8	8	....	....	....	....	....	....
20	2.8	21	....	....	....	....	....	....
30	4.9	35	2.3	....	....	....	0.77	....
40	6.6	47	5.3	....	3.0	....	.133	....
50	8.2	58	10.1	27	4.8	....	.202	0.54
60	9.6	66	15.8	57	5.7	30	.263	.96
70	10.9	72	21.1	90	5.3	33	.301	1.29
80	12.0	76	27.4	128	6.3	38	.343	1.60
90	13.0	80	34.0	160	6.6	32	.355	1.77
100	13.9	83	40.6	193	6.6	33	.406	1.93
110	14.7	85	46.3	228	5.7	35	.421	2.08
120	15.5	87	53.8	263	6.5	35	.448	2.19
130	16.1	88	59.0	286	5.2	33	.454	2.20
140	16.7	89	63.6	314	4.6	28	.454	2.25
150	17.3	90	69.4	345	5.8	31	.463	2.30
160	17.8	91	74.4	374	5.0	29	.465	2.34
170	18.4	91	79.3	405	4.9	31	.465	2.39
180	18.9	92	84.4	437	5.1	32	.469	2.43
190	19.5	92	89.3	470	4.9	33	.470	2.47
200	20.0	93	94.6	505	5.3	35	.473	2.52

YIELD.

The growth in diameter, height, and volume of individual Norway pine trees is of little aid in determining the yield per acre. Yields of stands of different ages are best found by actual measurements of stands of the age to be recorded. The yield of even-aged stands is then determined by multiplying the volume of the average tree by the number of trees on the area. The sample plots upon which Table 11 is based were located in Cass and Itasca Counties, Minn. The plots selected for measurement were completely stocked with pine. A mature and fully stocked Norway pine stand forms a practically complete crown cover. The crowns themselves are not dense nor is the shade deep, though it is usually sufficient to exclude from the dry and sandy forest floor practically all underbrush, leaving only a carpet of needles. At the age of 150 years, however, the stand begins to thin out, and by 200 years the canopy will be broken, with many blanks caused by the death of trees. The yield per acre at this time is actually less than at an earlier age.

The method followed in constructing Table 11 was to plot the yield of each sample plot on cross-section paper, on the basis of age. The space between the maximum and minimum curves was then divided into three parts, representing good, medium, and poor yields. These coincide roughly with the three qualities of soils upon which the plots were taken. A curve was then drawn through the center of each space representing the qualities, from which the yields for each age were read. In applying this table it should be remembered that the figures represent a theoretically perfect stand. Actual yields on

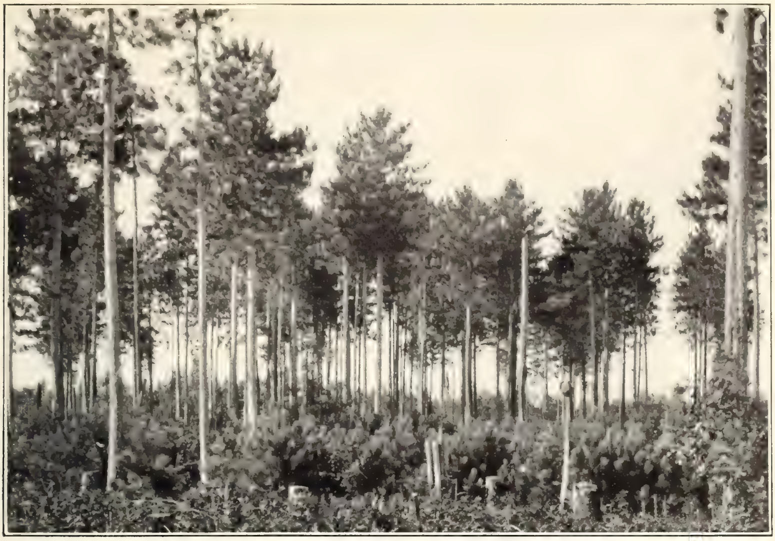


FIG. 1.—NORWAY PINE POLES AND SEEDLINGS, ROSCOMMON COUNTY, MICH.

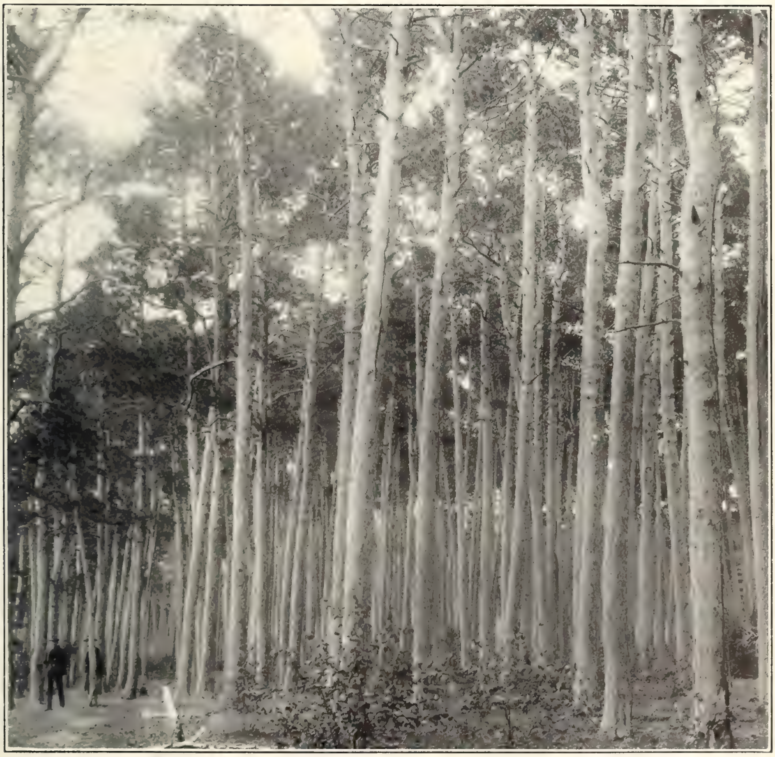


FIG. 2.—NORWAY PINE ON THE MINNESOTA NATIONAL FOREST.

sand barrens where there are small openings may, even in the case of plantations, be from three-fourths to one-fourth of these amounts. Table 11 is based on 85 sample plots from 40 to 200 years old.

TABLE 11.—*Yield per acre of fully stocked even-aged stands according to three quality classes.*

Age (years).	Yield per acre.		
	Quality I.	Quality II.	Quality III.
	Board ft.	*Board ft.*	*Board ft.*
40	4,100	2,000	......
50	9,400	6,100	2,800
60	15,100	10,200	5,300
70	20,900	14,300	7,900
80	26,500	18,600	10,700
90	32,300	22,900	13,700
100	38,500	27,400	16,900
110	44,700	32,000	20,100
120	50,800	36,700	23,100
130	56,800	41,200	25,800
140	60,500	43,900	27,900
150	62,300	45,700	29,500
160	63,300	46,900	30,600
170	63,700	47,500	31,100
180	63,700	47,700	31,300
190	63,000	47,300	31,300
200	61,800	46,500	31,000

The mean annual growth in board feet culminates on all the qualities of site at about 140 years. There is a slight further increase in volume until 170 years on Quality I, and to 180 years on Qualities II and III, but the mean annual growth per acre falls off, and soon the stand itself begins to lose in volume from windfalls, old age, and fire. The maximum mean annual yield on good soils hardly exceeds 400 per year, and on Quality III sites 200 feet. These yields are for natural Norway pine sites, whose quality is at best much below that of soils occupied by white pine and hardwoods. Since Norway pine will grow on any well-drained soil, if started in full sunlight, yields from plantations, even when unthinned, on the richer soils may amount to from 500 to 800 board feet per acre per year. Since Norway pine can form fully stocked stands only under ideal conditions of light and moisture, which are seldom met with in nature, the average stand per acre of pine, either Norway or white, actually comes nearer to being 5,000 or 10,000 feet, instead of the 40,000 or 60,000 feet yielded by fully stocked areas.

The openings in ordinary stands of Norway pine are occupied by poplar, birch, and scrub oaks, although none of these species do as well as Norway pine on sandy soils. Even if these inferior species could be utilized, nothing like the returns can be secured as from fully stocked stands of Norway pine. It is safe to say that with complete stocking the average production of large areas can be increased fivefold.

The number of trees on fully stocked areas depends in part on the width and shape of the crown. Table 12 gives an idea of the average width of crowns of trees of different diameters.

TABLE 12.—*The crown width of dominant trees on basis of diameter breast-high, Itasca County, Minn.*

[Based on 134 measurements.]

Diameter breast-high (inches).	Width of crown (feet).	Diameter breast-high (inches).	Width of crown (feet).
3	4	13	15
4	5	14	15
5	7	15	16
6	8	16	16
7	9	17	16
8	11	18	16
9	12	19	16
10	13	20	17
11	13	21	17
12	14		

The crowns of Norway pine trees are remarkably narrow compared with those of southern and western pines, which makes possible a larger number of trees per acre. An idea of the possible approximate yields which may be obtained under management is given in Tables 13 and 14. It can be assumed that with frequent thinnings the trees remaining in the stand will grow at the average rate of dominant trees and will have the width of crown indicated in Table 12. Assuming that the average volume of these trees will be that shown in Table 10, it is necessary only to know the average number of trees per acre in order to ascertain roughly the yield of such stands at a specified age.

The diameter of the average crown was squared in finding the number of such trees that could stand on an acre. Since crowns are circular, this introduced a factor of safety amounting to a reduction of 22 per cent of the number of trees which might otherwise be computed as having growing space, and gives a crown density of 78 per cent instead of 100 per cent.

TABLE 13.—*Yields per acre of dominant trees, calculated from diameter growth, average crown space, and number of trees per acre at different ages.*

Diameter breast-high (inches).	Age (years).	Volume of tree.	Trees per acre from curve, based on crown space.	Yields per acre.
		Board feet.	*Number.*	*Board feet.*
8	49	23	302	8,280
9	56	45	266	13,590
10	63	67	241	17,822
11	71	94	221	22,654
12	80	128	206	28,288
13	90	160	193	32,960
14	101	197	183	38,021
15	114	242	175	44,286
16	128	289	168	50,575
17	145	329	163	55,272
18	163	383	158	62,429
19	182	444	154	70,152
20	200	505	151	77,770

Column 2 of Table 13, which shows the age of trees of each diameter, was taken from Table 7, using the average figures of growth in the middle column of dominant trees. Much larger yields would have been indicated had the left-hand column been made the basis of the calculation.

Column 3 was obtained from Table 10, volume growth of Norway pine, Table 7, middle column, for diameter growth of dominant trees, and from Table 4, average height based on diameter of dominant trees.

Column 4 was obtained by squaring the crowns of trees of all diameter classes, computing the number of trees per acre for each class by dividing 43,560 by the square of the diameter of the crown, a density factor of 0.78 per cent, and then plotting the results and evening off by a curve for each diameter class.

Column 5 was obtained by multiplying column 3 by column 4.

Table 14 shows by decades the yields given in Table 13.

TABLE 14.—*Theoretical yield per acre of fully stocked stands, Quality I.*

Age (years).	Yields (board feet).	Age (years).	Yields (board feet).
50	8,400	130	50,400
60	14,600	140	54,000
70	22,000	150	57,600
80	27,600	160	61,000
90	33,000	170	64,000
100	37,700	180	66,900
110	42,300	190	69,500
120	46,500	200	72,000

These theoretical yields agree with those found by actual measurements of fully stocked stands on first quality sites. The actual yields slightly exceed those shown in Table 14, notably for the ages from 110 to 160 years. At 170 years the actual yields fall off rapidly, while the yields computed from crown space continue to increase even after the results are reduced by a curve. These facts indicate, first, that the rate of growth used in the calculation is actually attained by the greater number of trees forming a Norway pine stand on good soil, and, second, that the density of the crowns of such stands is greater than 0.78, which is the assumed factor of density obtained by squaring the crowns which are normally round. Finally, the divergence of yields for 170 years clearly indicates that at this age the natural stands begin to deteriorate and do not maintain the closed canopy. The decrease in the number of trees per acre resulting from this process of deterioration lowers the yield from then on. Individual Norway pines will live to be 300 years old, but plots much over 200 years old are composed either of the remnants of much denser stands or of the survivors of a struggle with jack pine.

It is an interesting fact that a Norway pine tree which has been stunted for from 30 to 50 years, if it recovers, adds that period to its normal life. This behavior has also been noticed in the case of tamarack and the giant sequoias of California. Table 15 gives some interesting figures of increment for 8 sample plots measured in pole stands. The volumes are computed to a 2-inch merchantable diameter on the basis of the average tree for each diameter class.

TABLE 15.[1]— *Yield per acre of fully stocked sapling and pole stands on good-quality soil.*

	Serial No. of plot.							
	1	2	3	4	5	6	7	8
	Location.							
	Release.	Grand Rapids.	Menahga.	Blackberry.	Cloquet.	Itasca Park.	Shevlin.	Itasca Park.
	Soil.							
	Sand.	Sandy loam.	Sandy clay.	Sandy clay.	Sandy clay.	Sandy clay.	Sandy clay.	Sandy clay.
Age of stand..........years	13	15	15	17	27	27	41	79
Average diameter breast-high..inches	2	3½	3½	4	5	5	4½	8½
Average total height..........feet	10½	22½	16½	20	29	21	40	69
Total number of trees per acre..........	1,720	2,616	713	778	1,512	874	616	524
Volume at present..........cubic feet	145	1,235	272	548	1,368	1,085	990	5,534
Volume 5 years ago..........do	....	121	55	74	647	548	455	4,620
Total increment last 5 years..........	....	1,114	217	474	721	537	535	919
Annual increment last 5 years..........	....	223	44	95	140	107	107	184
Average annual increment..cubic ft	11	82	18	32	50	40	24	73
Volume at present..........cords	2	17.3	3.8	7.7	19.1	15.2	14	79.5
Volume 5 years ago..........do	....	1.6	0.8	1.2	9.1	7.6	6.3	64.6
Total increment last 5 years..........	....	15.5	3	6.5	10	7.6	7.7	14.9
Annual increment last 5 years..........	....	....	....	1.3	2	1.5	1.5	3
Average annual increment....cords	0.15	1.3	0.25	½	0.7	0.56	0.34	1
Volume at present..........board feet	1,015	8,645	1,912	3,840	9,581	7,595	6,934	39,735
Volume 5 years ago..........do	....	849	383	525	4,530	3,838	3,187	32,332
Total increment last 5 years..........	....	7,798	1,519	3,318	5,047	3,757	3,745	7,403
Annual increment last 5 years..........	....	1,560	302	665	980	751	749	1,580
Average annual increment..board ft	77	643	126	224	350	281	169	503

The figures in the table would indicate a remarkably rapid growth. On the whole, however, it is clear that upon poor soils, and with the comparatively cool and short growing season, rapid growth and heavy yields can not be expected at an early age. The returns from either plantations or natural stands inside of 40 years will be negligible, yet in the end the species not only exceeds in the capacity for timber production any other species adapted to sandy soils in the North, but equals and probably exceeds in yield per acre the Scotch pine grown on similar soils in Europe. If such growth is possible in the more northern latitudes, and on the sandier soils, it should produce yields equal to or exceeding those of white pine at the southern limits of its range and on the richer soils occupied by hardwoods. This fact, when taken in connection with its immunity from the white-pine weevil and freedom from other forms of insect or fungous attacks, should give Norway pine an important place in future forest management.

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[1] Furnished by William T. Cox, State forester of Minnesota.

There is a tendency to use Scotch pine on soils suitable for Norway pine. The height growth of the Scotch pine exceeds that of the Norway for a few years, but the future development of the former species as a timber tree in America can not be predicted. Much Scotch pine seed is collected from stunted trees which can not produce sizes of commercial value. In Norway pine, on the other hand, the forester has a tree whose growth and development is absolutely certain, and therefore should be depended upon in large commercial plantations on poor soils.

MANAGEMENT.

RESULTS UNDER THE MORRIS ACT.

The only systematic attempt at management of Norway pine on a considerable scale has been made on the Minnesota National Forest, under the Morris Act of June 27, 1902. This act as passed provided that 5 per cent of the total volume of standing timber be left in seed trees. In 1908 an amendment to the bill doubled this percentage. When 5 per cent of the volume was left, there were from 0.2 to 1.5 seed trees per average acre, or about 0.6 seed trees per acre for the area as a whole. Cutting was begun in 1904, but the areas were burned over the same year, so the results from cutting 95 per cent of a Norway pine stand can not be predicted with certainty. Young growth has come in well on two areas where light fire, which cleared out the underbrush, was followed by a good seed crop. Owing to the rather open stand, averaging about 6,000 board feet per acre, considerable ground cover existed before the logging. Taken as a whole, the natural reproduction is not a success, because not enough seed fell immediately after logging, when the bared soil was in the best condition to receive it. What young growth there is has sprung up as the result of the chance combination of a good seed year with a suitable condition of the soil. Where conditions have been favorable, however, the results are unexpectedly good.

Before condemning the Morris Act because better results have not been obtained, one must bear in mind that as a forerunner of forest management in Minnesota it was necessarily a compromise between the clear cutting of the old-time lumberman and the ideal conservative fellings of the forester.

ROTATION.

The time at which Norway pine should be cut must be determined in each individual case. To grow sawtimber from 20 to 24 inches in diameter takes on the average Norway pine soil from 132 to 173 years. The average annual growth culminates at about 140 years on all sites, and consequently the rotation which would give the greatest volume production would be one of 140 years. If timber is cut when too young or too old the full productive capacity of the soil is not utilized, especially if the timber is cut clear. When natural reproduction is sought, particularly with the shelterwood system or from clear cutting, the stand should be felled if possible while the trees are producing seed prolifically, i. e., between 80 and 130 years.

Financial returns.—A long rotation means a larger growing stock or forest capital; and in compound interest calculations the interest on this standing timber more than counterbalances the sale value of the additional lumber produced. To illustrate this principle, according to Table 11 a Norway pine stand on Quality II soil[1] yields 10,200 board feet after 60 years, 18,600 after 80, 27,400 after 100, and 36,700 after 120 years. Table 16 shows the estimated returns on money invested in Norway pine stands when cut after 60, 80, 100, and 120 years. Compound interest has been figured at 4 per cent on an initial cost of $15 for land and young growth; taxes and fire protection at 4 cents per acre per year; and stumpage at $20, a very conservative figure, for the years 1973, 1993, and 2017.

TABLE 16.—*Revenue derived from the conservative management of Norway pine.*

Length rotation (years).	Yield from thinnings.	Final yield per acre.	$15 capital at 4 per cent compound interest.	Approximation of final yield per cent on original investment.
60	Estimated thinnings will pay cost of taxes and fire protection	$204.00	$157.79	4½—
80		372.00	345.74	4 +
100		548.00	757.57	3½+
120		734.00	1,659.94	3¼

Any forecast of future returns necessarily involves some elements of uncertainty. What will be the taxes, fire loss, or unforeseen injuries? Will natural reproduction be wholly or partially successful, or a total failure? What will be the stumpage price? At what figure should the land and timber be capitalized? It is certain that in 1950 Norway pine in the United States will bring at least as high a stumpage price as good Scotch pine in France and Germany brings now—from $12 to $24 per thousand board feet—probably 30 to 100 per cent more, since it now nets from $10 to $12 on the stump. But even with such an increase, the returns from forest investments extending over long periods of time are certain to be small as compared with returns from short-term investments.

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[1] All calculations are based on Norway pine growing on sandy soil, because this is the soil to which the tree is naturally adapted.

CLEANING OR WEEDING.

To produce timber of high quality it is essential in most cases to tend the stand practically from the start. One of the main cultural operations is to clean or weed the young stand of undesirable trees. While such an operation may be permissible from a financial standpoint in a mixed hardwood forest, it would scarcely be justified in the case of Norway pine. To clean or weed the young Norway pine stands will entail an expense of from $2 to $4 per acre. Two dollars at 5 per cent compound interest amounts to $697.82 for a rotation of 120 years, and few operators could afford this expenditure. Where the owner maintains a protective force the rangers may make systematic weedings. For example, if jack pine is temporarily suppressing the Norway pine, the ranger can top the jack pine and lessen the struggle for light. Norway pine seedlings under aspen or underbrush can be liberated. If this weeding can be done in connection with other duties, even at a small additional expense, it is certainly worth while. In Minnesota, for example, there are thousands of acres of natural forests of Norway pine, from 10 to 30 years old, which deserve attention from the owners, and which it would be profitable to hold in view of the increasing demand for small mine timbers.

THINNINGS.

The removal of undesirable or competing trees from a stand is called thinning. This reduces the loss which ordinarily takes place in the struggle for light. The silvicultural value of thinnings in Norway pine can not be questioned, although they are not of the same vital importance as in a mixed forest. In a widely spaced plantation thinnings would probably not be needed before the twentieth or thirtieth year, but will be necessary after that. Timely thinnings are important in securing natural reproduction, since they result in a final stand of trees with well-developed crowns, thus insuring abundant production of seed. Moreover, every lumberman would prefer to cut 88 20-inch boles, rather than 338 13-inch,[1] because wide lumber brings better prices than narrow boards. Under present conditions thinnings on a large scale are justified only when the sale of the products at least pays the cost. The owner of a small area of timber can improve his stand without expense by selecting the small poles needed for farm construction from dense groups of Norway pine, instead of adopting the possibly more convenient procedure of cutting a portion of his woodlot clear. Thinnings in pine stands should begin early, and be made lightly and often. In a dense Norway pine stand the first thinning should be made when the trees are from 20 to 30 years old, removing from 10 to 15 per cent of the stand. After that, they should be repeated every 7 or 10 years. In practice, however, this can rarely be carried out, because of the present lack of market for small saplings and the prohibitive cost of logging scattered trees. Thinnings in young pine stands should not be heavy or the height growth will be impaired. The trees will not prune so well, and the soil will not be sufficiently shaded toward the end of the rotation to prevent weeds from getting a foothold and endangering reproduction. Heavy thinnings, moreover, are likely to result in windfall, as was well illustrated in the case of the thinned stand of Norway and white pine on the Grand Marais Lighthouse Reservation a few years ago. The winds off Lake Superior are very heavy at times. Many of the trees left standing on the lighthouse reservation lean badly and appear to have their roots loosened. In this case the thinning was probably deferred too long and then made too heavy.

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[1] See Table 11 for yield data on unthinned stands on Quality II soil.

IMPROVEMENT CUTTINGS.

In mature and overmature stands where, as in the case of parks, the aim is not so much to secure young growth as to maintain the present stand, loss would be avoided if systematic improvement cuttings are made at intervals of from 15 to 25 years. The Norway pine trees removed should be those with straggling and light-green foliage, stag-headed, or clearly so overmature that they will not survive until the next cutting. It would be better even to cut a few healthy trees in clumps, in order to increase the amount to be logged per acre, than not to cut at all. When an overmature forest is cut systematically, it is possible to clear up the occasional windfalls, which are bound to occur in old age.

MANNER OF CUTTING.

In any partial cut of the stand the trees to be removed should be marked beforehand, in order to insure that the thinning will be carried out as planned. The method usually followed is to blaze or stamp the roots and bole of the trees to be cut. Close utilization of the material marked is even more important. The owner should see to it that stumps are cut low (from 12 to 16 inches, depending on the size of the timber), the tops utilized to the full merchantable limit (in the Lake States usually 6 inches), and that logs partially defective are removed, even if they contain only from 20 to 25 per cent of merchantable material. It is, of course, necessary to use great care not to damage reproduction which is to form the second crop. Roads, skidding trails, skidways, and the cutting of seed trees should be designed with this in view.

NATURAL REPRODUCTION.

The aim should always be to secure a second crop by natural seeding of the ground by the trees in the original stand. This can be insured in most cases by proper methods of cutting. Artificial sowing or planting, because of the initial cost[1] and because of low stumpage prices, should be resorted to only when natural reproduction fails. Even after reasonably successful reproduction takes place there will be fail places or blanks. Where the stand is open and overmature, forestation may be the only certain means of securing a new crop of Norway pine. Where sowing or planting is impracticable, the forest soil of the Lake States will, if protected from fire, still restock naturally, though with some such species as aspen or birch. These, while not as valuable as Norway pine, bring—in Maine, for example—from $3 to $10 an acre. They also have the advantage of rapid growth and ease of reproduction.

There are several methods of cutting Norway pine to secure natural reproduction, although no one has been tried out long enough to establish it as superior to any other. These methods are (1) shelterwood system, (2) group selection system, (3) clear cutting and (4) leaving seed trees. No matter which of these systems is followed, it must, in virgin stands, assume the character of a heavy improvement cutting.

Shelterwood system.—The shelterwood system of cutting—i. e., the removal of the stand in two successive cuttings—has been suggested as the ideal method of securing reproduction of Norway pine.[2] This system, however, would probably be better adapted to white pine than to Norway, because the former reproduces better under a partial shade. If applied to Norway pine, the parent stand should be removed before the seedlings suffer from suppression. If reproduction came in within a year after the first cutting, the parent stand could safely be removed from 4 to 7 years later. Until fire protection is more certain it would, perhaps, be better to leave scattered seed trees even after the second or final cutting, until the new crop reaches the sapling or pole stage. This would have its disadvantages, of course, on account of the additional cost of logging and the unavoidable damage to the young growth in cutting. Another alternative would be not to cut these "safety seed trees," but to leave them for increased growth during the entire rotation. With the shelterwood system it is important to keep close check on the progress of reproduction after the first cutting. The owner should not only guard against the suppression of the seedlings, but he should also prevent the soil from becoming so covered with brush and weeds that even forestation is made impossible through the prohibitive expense of clearing the soil. It is often practicable to assist reproduction by partial sowing or planting within a few years after cutting, before the soil becomes choked with weeds.

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[1] Mr. William T. Cox, State forester of Minnesota, states that planting has been carried on successfully in parts of Minnesota for from $3.50 to $6 per acre.

[2] "Results of cuttings on the Minnesota National Forest under the Morris Act of 1902," Proceedings of the Society of American Foresters, p. 104, Raphael Zon.

Group selection system.—Cutting Norway pine in irregular selected groups of from 2 to 10 trees may be advisable: (1) Where for æsthetic or protective purposes a mature stand must be maintained; or (2) where the fire danger is very acute and continuous areas of even-aged stands, such as would result from the shelter-wood system, must be avoided. The selection method of cutting is always more costly for the lumberman, and invariably results in considerable damage to the young growth. Theoretically not more than one-fourth to one-third of the stand should be cut at any one time, but in practice the lumberman may be compelled to take out one-half or more and wait a longer time between cuttings. There will always be danger of weeds unless the cutting can be made closely to coincide with good seed years, followed by favorable climatic conditions to insure immediate seeding. In a large operation, where cutting must be done every year, this would obviously be impracticable.

Clear cutting.—Clear cutting in strips or blocks would reduce the cost of logging, but it has the danger of opening the soil to weeds, and hence should be tried only if it can be done during or immediately following a good seed year; otherwise, planting may be necessary. The portion of the stand uncut should be north or west, as well as to the windward of the area to be restocked, in order that the ground may be kept as moist as possible. If there is not successful restocking within a few years, planting should be resorted to, where it can be done at a reasonable expense, before the ground has a chance to become choked with weeds and brush.

Seed trees.—The plan of leaving scattered seed trees has on the whole proved unsatisfactory. This system is really a compromise; it is neither clear cutting nor partial cutting, for a few seed trees per acre are insufficient fully to seed up the ground. As generally practiced, from 3 to 10 seed trees are left per acre, the more the better so far as the future reproduction is concerned. If logging can always be done at the time of a good seed crop satisfactory results may be obtained, since the soil after being stirred up by hauling and skidding offers a good germinating bed. With a mature stand windfall and sun scald are likely. About one-fourth of the seed trees on the Minnesota Forest have blown down. Yet owners may prefer to secure a very partial crop of the original species by this method on account of the small amount of merchantable timber which has to be left. The seed trees could be held over a rotation to yield lumber of large size as a provision against loss of the second growth by fire, or cut when no longer needed for purposes of seeding.

ARTIFICIAL REPRODUCTION.

Where natural reproduction fails, or where the land has been denuded, sowing and planting is the only way to secure a new timber crop. The greatest drawback to the use of Norway pine for artificial reforestation is the scarcity and high cost of the seed and the slightly lower stumpage price as compared with white pine. Norway pine, however, has advantages which white pine does not possess. It will grow better on sandy soil; it is hardier and less subject to natural injuries; it prunes itself earlier, and on poor soils produces more wood. Scotch pine is often recommended in preference to Norway, because the seed is cheaper and the plants are fully as hardy.

Opinion among foresters concerning the relative merits of Scotch and Norway pine for planting in the Lake States is somewhat divided. Up to the present the consensus of opinion has usually been in favor of Scotch pine, especially in southern Minnesota, on account of its alleged greater hardiness. If planted on a large scale for forest purposes, however, Norway pine has given good results. The fact that it is a native species gives a greater assurance of safety than would the planting of Scotch pine, of which there are as yet no mature forests in this country.

Sowing of Norway pine on the whole has not been successful in the past, and planting has been found the better method. Measurements of Norway pine in New England show the average growth to be greater than that of white pine. On sand, containing varying proportions of loam, 40,758 white pine, 30 years old, averaged 26.6 feet in height and 3.7 inches in diameter, while 40,538 Norway pine of the same age averaged 35.4 feet in height and 5.9 inches in diameter. On richer soil, 1,758 white pine, 27 years old, averaged 43.5 feet in height and 5.18 inches in diameter, while 19 Norway pine were on the average 48 feet high and 6.6 inches in diameter.[1]

Although the seed usually begins to fall after the first week in October, it should be collected in late August, September, or early October. The date when it matures varies, of course, with the weather conditions from year to year. The cost of collecting it has been from $2 to $3.06 a pound and higher. Regular seed dealers ask from $4 to $12 a pound for small lots. According to the Forest Service, a bushel of cones will average 1 pound of seed. A pound contains from 55,000 to 70,000 individual seeds, with an average germination per cent of 89. In the Georgian Bay region, forty-fifth parallel of latitude, Norway pine seed was found by Zavitz to average only 0.26 of a pound to the bushel and 52,000 seed to the pound. After cleaning, germination tests in the greenhouse gave 94 per cent.

A great deal of original work has been done in the collection and extraction of Norway pine seed by Kennety at the Cloquet Experiment Station, in Minnesota. Two methods of seed collecting have been tried out at the experiment station. One was to follow the logging crew and gather the cones as the trees were felled. The other was to collect the cones from squirrel hordes. The latter method was found to be by far the best. Thus, when collecting the cones from felled trees from 1 to 2 bushels was the average per man per day; from 1 to 4 bushels was the average collected from squirrel hordes. The largest caches of Norway pine found contained 1 bushel, while caches consisting of jack pine and Norway pine cones often held 2 bushels. The average number of seed from cones was found to be 37, of which 23 were good and 14 bad.

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[1] Measurements made by H. B. Kempton.

In general it was found that temperatures from 130° to 140° were the ones at which the seed could be extracted easiest with the highest percentage of germination. While for all temperatures used in the test the mean per cent of germination was 70.8, for 130° to 140° the per cent was 78.5. The lower germination per cent for temperatures of less than 130° is accounted for by the fact that at that temperature only the smaller and less fertile seed are released. In Table 17 is given the length of time necessary for Norway pine to crack and open at different temperatures.

TABLE 17.—*Length of time necessary for Norway pine cones to crack and open at different temperatures.*

Temperature.	Cracking.		General opening.		Not open.
°	*H.*	*m.*	*H.*	*m.*	*Per cent.*
125	1	20	4	35	12
130	1	15	4	15	14
135	1	30	4	0	14
140		45	3	45	8
145		40	2	30	8
150		40	2	22	4
155		50	2	25	6
160		45	2	30	2
165		40	2	15	
170		35	2	20	2
175		15	2	0	
200		15	1	30	

SOWING.

Sowing is best done when the ground is free from weeds after logging. If the seed averages 55,000 to the pound, with a germinating per cent of 90, broadcasting would require about 5 pounds per acre. With the seed costing $4.50 a pound, sowing broadcast under these circumstances would be absolutely prohibitive. In any event, broadcasting will rarely be successful unless the soil is harrowed and raked clear of weeds, though this would not be necessary on soil cleared by fire directly after logging. It may often be practicable to supplement natural regeneration by broadcasting on a soil bared by logging when there is no seed crop.

Sowing in seed spots is cheaper. With spots 2 feet square and 8 feet apart and with 40 seed to the spot a little over a pound per acre would be sufficient. If the seed spots were spaced 6 by 6 feet, the total number of seed needed per acre would be 48,400, a little less than a pound. Seed-spot sowing should not be attempted without proper preparation of the ground, and often some kind of a brush cover will be necessary to prevent the seedlings from being dried out after germination. Mr. J. F. Kendrick, of South Orleans, Mass., secured excellent results on a pure sand by the following method:

> The owner at one time attempted to farm this soil, and the year previous to starting the plantation rye was sown on the area, while during the year preceding that a crop of corn was produced. The plantation was started simply by dropping seed in the corn hills after making a small hole with a dibble. The spacing was about 4 by 4 feet. After 35 years the dominant trees were 7–8 inches diameter breast-high and 38–40 feet tall, in excellent condition, were clearing themselves well, and apparently growing vigorously.

PLANTING.

Norway pine should be planted pure or with some more tolerant species of slower growth. Planting in the early spring is preferable to that in the summer or fall. Transplants are better than seedlings, but on good soil the latter should succeed. Ordinarily it will be necessary to raise stock in the nursery, preferably near the planting site, if the planting is on a large scale. Occasionally it may be possible to transplant seedlings growing in the forest, but these give less certain results than nursery grown stock, although success with wild stock at very low cost has been reported from the Minnesota National Forest.

BRUSH DISPOSAL.

Protection of stands from fire is obviously the first step in forest management. In 1911 the loss from forest fires in the Lake States totaled $3,368,000, most of it in the pineries. As a fire-protection measure the disposal of slash [1] is of great importance. Most of the great fires in the Lake States assumed the character of conflagrations by being able to feed upon the débris left after logging. In Norway pine stands, piling and burning the brush is a prudent and essential insurance against fire. The brush is piled and burned in winter as the cutting proceeds. The cost varies from 10 to 35 cents per thousand board feet logged. On the Minnesota National Forest the average cost has been about 16 or 19 cents. Where the timber is scattering, and the fire risk proportionately small, it is usually sufficient to clear and burn fire lines intersecting and around the cut-over areas. These lines should rarely be less than 150 feet in width.

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[1] Under the Minnesota forest law the State forester is given authority to enforce the proper disposal of débris after logging.

APPENDIX.

VOLUME TABLES.

The tables which follow are based on volume analyses taken in Minnesota and Wisconsin, chiefly under the supervision of E. S. Bruce, expert lumberman. The board-foot volumes were calculated by the Scribner Rule, decimal C. In these tables no allowance has been made for defect, which must be estimated in the forest. The top cutting limit used was 6 inches inside bark.

Table 18 gives the volume in board feet for trees of all diameters, and for 16-foot logs and half lengths or 8 foot differences in merchantable height. The extremely large number of trees upon which the table is based (4,282 trees) makes its contents very reliable. The average stump height of the trees analyzed was 2 feet; the top diameter inside bark 6 inches. Usually 0.3 of a foot was allowed for trimming.

TABLE 18.—*Volume of red vine in board feet on basis of diameter, merchantable length in 16-foot logs.*

Diameter breast-high (inches).	Number of 16-foot logs.												
	1	1½	2	2½	3	3½	4	4½	5	5½	6	6½	7
	Volume (board feet).												
8	20	30	40	53	......	......	......	......	......	......	......	......	......
9	20	34	48	63	77	......	......	......	......	......	......	......	......
10	20	41	57	73	89	100	......	......	......	......	......	......	......
11	20	42	62	83	100	120	140	......	......	......	......	......	......
12	20	52	74	96	120	140	160	190	......	......	......	......	......
13	20	56	83	110	130	160	180	210	240	......	......	......	......
14	20	63	96	120	150	180	210	240	270	......	......	......	......
15	......	71	110	140	170	200	230	270	300	340	......	......	......
16	......	78	120	150	190	230	260	300	340	380	......	......	......
17	......	......	130	170	210	250	300	340	390	430	480	......	......
18	......	......	140	190	230	280	330	380	440	490	550	......	......
19	......	......	......	200	260	320	380	430	490	550	620	680	......
20	......	......	......	220	290	350	420	490	550	620	680	750	820
21	......	......	......	......	310	390	470	540	610	680	750	820	880
22	......	......	......	......	340	430	520	600	680	750	820	890	950
23	......	......	......	......	380	480	570	660	740	820	890	960	1,030
24	......	......	......	......	420	530	630	730	820	900	970	1,040	1,110
25	......	......	......	......	......	600	700	790	890	980	1,060	1,130	1,200
26	......	......	......	......	......	660	760	860	960	1,060	1,140	1,230	1,310
27	......	......	......	......	......	720	830	940	1,040	1,140	1,240	1,330	1,430
28	......	......	......	......	......	790	900	1,010	1,120	1,230	1,350	1,450	1,560
29	......	......	......	......	......	......	960	1,080	1,200	1,330	1,450	1,580	1,700
30	......	......	......	......	......	......	1,030	1,160	1,300	1,430	1,570	1,710	1,850
31	......	......	......	......	......	......	1,100	1,240	1,390	1,530	1,690	1,840	2,000
32	......	......	......	......	......	......	......	1,330	1,490	1,650	1,820	1,980	2,140
33	......	......	......	......	......	......	......	1,420	1,590	1,770	1,950	2,130	2,300
34	......	......	......	......	......	......	......	1,520	1,710	1,900	2,090	2,280	2,480

The use of total heights instead of merchantable height is possible with a species as regular in form and as free from heavy top branches as is the Norway pine. Where this is done, the error arising from failure to employ the top diameters used in timber estimating, can not affect the results beyond the amount of the difference in the used volume or waste in the tops. Total height is a more accurate basis for estimating volumes than arbitrary merchantable heights for all species which have a regular form and are utilized closely in the tops. Table 19 gives the volumes of Norway pine in board feet classified by 10-foot differences in height, based on the 4,282 trees measured for Table 18.

Table 19.—*Volume of Norway pine, in board feet, on basis of diameter, total height in feet.*

Diameter breast-high (inches).	Average for all heights.	Height of tree (feet).									
		30	40	50	60	70	80	90	100	110	120
	Volume (board feet).										
8	24	10	13	17	26	34	46	53	65		
9	43	14	20	28	39	51	64	77	92		
10	66	20	28	40	53	68	86	100	120		
11	90		38	53	69	87	110	130	150		
12	120		48	67	86	110	130	150	180	210	
13	150		60	81	100	130	160	180	210	240	
14	190		70	96	120	160	190	210	250	280	
15	230			110	150	180	220	250	290	320	
16	270			130	170	210	250	290	330	360	390
17	320			140	190	240	290	330	370	410	440
18	370			160	220	280	330	380	420	460	500
19	430				260	320	380	430	480	520	560
20	490				290	360	430	490	540	590	630
21	560					400	480	550	610	670	710
22	640					450	540	620	690	750	800
23	720					500	600	680	760	830	890
24	810					550	660	760	850	920	990
25	910					600	720	840	940	1,020	1,090
26	1,010					660	790	920	1,030	1,120	1,200
27	1,120						860	1,000	1,120	1,220	1,310
28	1,240						940	1,090	1,220	1,330	1,430
29	1,360						1,020	1,170	1,320	1,440	1,560
30	1,480						1,090	1,260	1,420	1,560	1,700
31	1,610							1,360	1,530	1,690	1,850
32	1,760							1,460	1,640	1,820	2,000
33	1,910							1,550	1,750	1,960	2,160
34	2,070							1,650	1,870	2,100	2,320

The cubic volume, without bark, for trees up to 20 inches in diameter, is given in Table 20, which is based on 303 trees. Table 21 is the same except that the bark has been included.

Table 20.—*Volume of peeled Norway pine, in cubic feet, on basis of diameter, total height in feet.*

Diameter (inches).	Height of tree (feet).						
	40	50	60	70	80	90	100
	Peeled volume (cubic feet).						
5	2.7	3.3	4.2				
6	3.8	4.8	5.8				
7	5.0	6.3	7.8	9.0			
8	6.5	8.2	10.1	11.9	13.9		
9	8.1	10.2	12.6	15.0	17.5	19.8	
10	9.9	12.6	15.3	18.2	21.0	24.0	27.0
11		15.2	18.3	21.0	25.0	29.0	32.0
12		18.2	21.0	25.0	29.0	34.0	38.0
13		21.0	25.0	29.0	34.0	39.0	45.0
14			29.0	33.0	39.0	46.0	52.0
15				37.0	44.0	52.0	60.0
16					51.0	60.0	68.0
17					57.0	67.0	77.0
18					64.0	75.0	86.0
19					71.0	83.0	94.0
20					79.0	91.0	103.0

TABLE 21.—*Volume of Norway pine with bark, in cubic feet, on basis of diameter, total height in feet.*

[Calculated from form factors of 306 Trees.]

Diameter breast-high (inches).	Height (feet).								Form factor.
	40	50	60	70	80	90	100	110	
	Volume (cubic feet).								
5	3.0	3.7	4.4						0.542
6	4.2	5.3	6.4	7.4					.540
7	5.8	7.2	8.6	10.1	11.5				.538
8	7.5	9.4	11.2	13.1	15.0	16.8			.536
9	9.4	11.8	14.2	16.5	18.9	21.0	24.0		.534
10	11.6	14.5	17.4	20.0	23.0	26.0	29.0		.533
11	14.0	17.5	21.0	25.0	28.0	32.0	35.0	39.0	.531
12	16.7	21.0	25.0	29.0	33.0	37.0	42.0	46.0	.530
13	19.5	24.0	29.0	34.0	39.0	44.0	49.0	54.0	.529
14	23.0	28.0	34.0	40.0	45.0	51.0	56.0	62.0	.528
15	26.0	32.0	39.0	45.0	52.0	58.0	65.0	71.0	.527
16		37.0	44.0	51.0	59.0	66.0	73.0	81.0	.526
17		41.0	50.0	58.0	66.0	74.0	83.0	91.0	.525
18		46.0	56.0	65.0	74.0	83.0	93.0	102.0	.524
19			62.0	72.0	82.0	93.0	103.0	113.0	.523
20			68.0	80.0	91.0	102.0	114.0	125.0	.522
21			75.0	88.0	100.0	113.0	126.0	138.0	.522
22				96.0	110.0	124.0	138.0	151.0	.521
23				105.0	120.0	135.0	150.0	165.0	.520
24				114.0	130.0	147.0	163.0	179.0	.519

By a comparison of Table 20 and Table 22 which follows, and by referring to the study of specific gravity, page 8, it is possible to determine approximately what sizes of trees can be driven without danger of expensive loss through sinkers.

TABLE 22.—*Volume of Norway pine sapwood, in cubic feet, on basis of diameter, total height in feet.*

Diameter breast-high (inches).	Total height of tree (feet).							
	40	50	60	70	80	90	100	110
	Volume of sapwood (cubic feet).							
5	2.3	2.6	3.0					
6	3.2	3.9	4.5					
7	4.2	5.3	6.1	6.5				
8	5.2	6.8	8.0	8.6	8.8			
9	6.4	8.5	10.2	11.1	11.6			
10	7.8	10.4	12.4	13.7	14.5	15.4	16.3	
11	9.3	12.3	14.7	16.4	17.6	12.5	19.6	
12	10.8	14.2	16.9	19.0	21.0	22.0	23.0	24
13			19.2	21.0	23.0	25.0	26.0	27
14			21.0	24.0	26.0	28.0	29.0	31
15				26.0	28.0	30.0	32.0	34
16				28.0	31.0	33.0	35.0	38
17					33.0	35.0	38.0	40
18					34.0	37.0	40.0	43
19					36.0	39.0	42.0	44
20					37.0	40.0	43.0	46

Table 22 was computed from the form factors for Norway pine. The form factor is the ratio between the volume of the tree and that of a cylinder with the same total height and diameter at 4½ feet from the ground. Trees of the same diameter and height may vary in form and volume considerably. Those trees which most closely approach cylindrical form contain the greatest volume and have the largest form factors. Old trees, with short crowns and long clear boles, which have grown in dense stands, have the fullest form, while young, rapidly growing, open-grown trees with short boles and long crowns will have the least volume for their diameter and height. Yet saplings grown in crowded stands may have a very high form factor, as may be seen in Table 23, which gives the factors for Norway pine of different heights and diameters and an average form factor for all heights on the basis of diameter; 306 trees were measured for this table.

TABLE 23.—*Form factors of Norway pine, on basis of volume in cubic feet, based on diameter and total height in feet.*

Diameter breast-high (inches).	Total height of tree (feet).							
	40	50	60	70	80	90	100	All heights.
	Form factor.							
5	0.567	0.576	0.584					0.542
6	.553	.562	.569	0.576				.540
7	.541	.549	.556	.561				.538
8	.529	.538	.544	.549	0.557			.536
9	.519	.527	.534	.539	.547	0.555		.534
10	.510	.519	.527	.532	.540	.548	0.553	.533
11	.502	.511	.520	.526	.534	.542	.549	.531
12	.495	.505	.514	.521	.530	.538	.546	.530
13	.489	.499	.509	.517	.526	.535	.543	.529
14		.495	.505	.513	.523	.532	.540	.528
15		.491	.502	.510	.521	.529	.537	.527
16			.499	.507	.517	.526	.534	.526
17				.505	.514	.523	.531	.525
18				.503	.512	.520	.529	.524
19				.501	.509	.518	.527	.523
20					.507	.515	.524	.522
21					.504	.513	.522	.522
22					.502	.511	.520	.521

Converting factors by which cubic volumes may be expressed in equivalent board-feet contents, are shown in Table 24 for trees from 8 to 20 inches and 80 feet high. This was obtained by dividing the values in Table 21.

TABLE 24.—*Board feet—cubic-foot converting factors for Norway pine trees 80 feet in height on basis of diameter.*

Diameter breast-high (inches).	Converting factor.	Diameter breast-high (inches).	Converting factor.
8	3.3	15	5.0
9	3.7	16	5.0
10	4.1	17	5.1
11	4.4	18	5.2
12	4.5	19	5.3
13	4.7	20	5.4
14	4.9		

Column 2 shows that for a tree 10 inches in diameter, breast-high, every cubic foot of volume in the tree is equal to 4.1 board feet, as determined by the Scribner rule, decimal C.

This table emphasizes the progressive increase in proportional board-foot contents of Norway pine, with increasing size, and the impossibility of converting cubic contents into board feet by a single multiple or ratio; these ratios apply only to the contents expressed by the Scribner rule.

The volume table is made by totaling for each tree the contents of logs of different diameters. No two log rules give the same contents in board feet for the same sized log, nor do they maintain the same proportional difference for logs of different sizes. Only by knowing the actual diameters of the logs in each tree can its volume by a new log rule be ascertained. Standard measurements of trees should for this reason be taken at definite intervals on every tree and averaged for trees of the same diameter and height. A table prepared in this manner, gives the average upper diameters of trees of all sizes and serves as a standard from which the volume may be found in any log rule or for any other unit of volume.

In Table 25, the results of 4,559 trees are averaged at points every 8 feet above an average stump height of 2 feet. An average length of 0.3 foot has been allowed on each 16-foot length for trimming.

TABLE 25.—*Diameter inside bark of Norway pine logs at intervals of 8.15 feet, on the basis of diameter, classed by trees of different heights.*

Diameter breast-high (inches).	Merchantable length (feet) including stump height.												
	10.15 [1]	18.3	26.45	34.6	42.75	50.9	59.05	67.2	75.35	83.5	91.65	99.8	107.95
	(Diameter inside bark inches).												
	30-foot trees.												
2	1.3	1.1	......	......	......	......	......	......	......	......	......	......	......
3	2.3	1.9	......	......	......	......	......	......	......	......	......	......	......
4	3.1	2.5	......	......	......	......	......	......	......	......	......	......	......
5	4.0	3.3	......	......	......	......	......	......	......	......	......	......	......
6	4.9	3.9	......	......	......	......	......	......	......	......	......	......	......
7	5.9	4.5	......	......	......	......	......	......	......	......	......	......	......
8	6.6	5.1	......	......	......	......	......	......	......	......	......	......	......
9	7.5	5.6	......	......	......	......	......	......	......	......	......	......	......
10	8.3	6.1	......	......	......	......	......	......	......	......	......	......	......
	40-foot trees.												
2	1.6	1.4	1.0	......	......	......	......	......	......	......	......	......	......
3	2.5	2.2	1.6	......	......	......	......	......	......	......	......	......	......
4	3.3	2.9	2.2	......	......	......	......	......	......	......	......	......	......
5	4.2	3.7	2.8	......	......	......	......	......	......	......	......	......	......
6	4.9	4.3	3.3	......	......	......	......	......	......	......	......	......	......
7	5.8	5.1	3.9	......	......	......	......	......	......	......	......	......	......
8	6.7	5.8	4.4	......	......	......	......	......	......	......	......	......	......
9	7.5	6.5	4.8	......	......	......	......	......	......	......	......	......	......
10	8.4	7.1	5.3	......	......	......	......	......	......	......	......	......	......
11	9.3	7.7	5.7	......	......	......	......	......	......	......	......	......	......
12	10.1	8.3	6.1	......	......	......	......	......	......	......	......	......	......
13	11.0	9.1	6.5	......	......	......	......	......	......	......	......	......	......
14	11.9	9.7	6.9	......	......	......	......	......	......	......	......	......	......

[1] The stump height is 2 feet.

Table 25.—*Diameter inside bark of Norway pine logs at intervals of 8.15 feet, on the basis of diameter, classed by trees of different heights*—Continued.

Diameter breast-high (inches).	Merchantable length (feet) including stump height.												
	10.15[1]	18.3	26.45	34.6	42.75	50.9	59.05	67.2	75.35	83.5	91.65	99.8	107.95
	Diameter inside bark (inches).												
	50-foot trees.												
4	3.4	3.1	2.7	2.1	......	......	......	......	......	......	......	......	......
5	4.3	4.0	3.4	2.6	......	......	......	......	......	......	......	......	......
6	5.0	4.7	4.1	3.1	......	......	......	......	......	......	......	......	......
7	5.9	5.4	4.7	3.6	......	......	......	......	......	......	......	......	......
8	6.8	6.2	5.4	4.1	......	......	......	......	......	......	......	......	......
9	7.6	6.9	6.0	4.7	......	......	......	......	......	......	......	......	......
10	8.5	7.7	6.6	5.1	......	......	......	......	......	......	......	......	......
11	9.4	8.4	7.3	5.6	......	......	......	......	......	......	......	......	......
12	10.3	9.1	7.9	6.1	......	......	......	......	......	......	......	......	......
13	11.2	9.9	8.5	6.6	......	......	......	......	......	......	......	......	......
14	12.1	10.6	9.1	7.1	......	......	......	......	......	......	......	......	......
15	12.9	11.5	9.8	7.5	......	......	......	......	......	......	......	......	......
16	13.8	12.1	10.4	8.0	......	......	......	......	......	......	......	......	......
17	14.7	12.9	11.1	8.5	......	......	......	......	......	......	......	......	......
18	15.6	13.7	11.7	8.9	......	......	......	......	......	......	......	......	......
	60-foot trees.												
4	3.5	3.3	3.0	2.5	2.1	1.3	......	......	......	......	......	......	......
5	4.3	4.0	3.7	3.1	2.5	1.6	......	......	......	......	......	......	......
6	5.2	4.8	4.4	3.8	3.0	1.9	......	......	......	......	......	......	......
7	6.0	5.5	5.1	4.4	3.5	2.3	......	......	......	......	......	......	......
8	6.9	6.4	5.9	5.0	4.1	2.6	......	......	......	......	......	......	......
9	7.7	7.1	6.5	5.7	4.5	2.9	......	......	......	......	......	......	......
10	8.6	7.9	7.3	6.3	5.1	3.2	......	......	......	......	......	......	......
11	9.5	8.7	8.0	7.0	5.5	3.5	......	......	......	......	......	......	......
12	10.4	9.5	8.7	7.6	6.0	3.8	......	......	......	......	......	......	......
13	11.3	10.3	9.4	8.2	6.5	4.1	......	......	......	......	......	......	......
14	12.2	11.1	10.2	8.8	7.0	4.4	......	......	......	......	......	......	......
15	13.1	11.9	10.8	9.4	7.5	4.7	......	......	......	......	......	......	......
16	14.0	12.7	11.6	10.1	8.0	5.0	......	......	......	......	......	......	......
17	14.9	13.5	12.3	10.7	8.5	5.3	......	......	......	......	......	......	......
18	15.8	14.3	12.9	11.3	9.0	5.6	......	......	......	......	......	......	......
19	16.7	15.1	13.7	12.0	9.5	5.9	......	......	......	......	......	......	......
20	17.5	15.8	14.4	12.5	10.0	6.1	......	......	......	......	......	......	......
21	18.4	16.7	15.1	13.2	10.4	6.5	......	......	......	......	......	......	......
22	19.3	17.5	15.8	13.8	11.0	6.7	......	......	......	......	......	......	......
	70-foot trees.												
6	5.2	4.9	4.6	4.3	4.0	3.6	2.6	......	......	......	......	......	......
7	6.1	5.7	5.3	5.0	4.5	4.0	2.9	......	......	......	......	......	......
8	7.0	6.5	6.1	5.7	5.1	4.5	3.1	......	......	......	......	......	......
9	7.8	7.2	6.8	6.4	5.7	4.9	3.4	......	......	......	......	......	......
10	8.6	8.1	7.6	7.0	6.3	5.3	3.7	......	......	......	......	......	......
11	9.5	8.9	8.4	7.7	6.9	5.7	3.9	......	......	......	......	......	......
12	10.5	9.8	9.1	8.5	7.5	6.2	4.2	......	......	......	......	......	......
13	11.4	10.5	9.9	9.1	8.1	6.6	4.4	......	......	......	......	......	......
14	12.3	11.4	10.6	9.8	8.7	7.1	4.7	......	......	......	......	......	......
15	13.2	12.3	11.4	10.5	9.3	7.5	5.0	......	......	......	......	......	......
16	14.1	13.1	12.2	11.3	9.9	8.0	5.2	......	......	......	......	......	......
17	15.0	14.0	13.0	11.9	10.4	8.4	5.4	......	......	......	......	......	......
18	15.9	14.9	13.8	12.6	11.0	8.9	5.7	......	......	......	......	......	......
19	16.8	15.7	14.5	13.2	11.5	9.3	5.9	......	......	......	......	......	......
20	17.7	16.6	15.3	13.9	12.2	9.7	6.1	......	......	......	......	......	......
21	18.7	17.5	16.1	14.5	12.7	10.2	6.4	......	......	......	......	......	......
22	19.6	18.3	16.9	15.3	13.3	10.6	6.6	......	......	......	......	......	......
23	20.5	19.2	17.7	15.9	13.7	11.1	6.9	......	......	......	......	......	......
24	21.5	20.0	18.5	16.6	14.3	11.5	7.1	......	......	......	......	......	......
25	22.4	20.9	19.2	17.2	14.9	11.9	7.3	......	......	......	......	......	......
26	23.3	21.8	20.1	18.0	15.5	12.3	7.6	......	......	......	......	......	......

[1] The stump height is 2 feet.

TABLE 25.—*Diameter inside bark of Norway pine logs at intervals of 8.15 feet, on the basis of diameter, classed by trees of different heights*—Continued.

Diameter breast-high (inches).	Merchantable length (feet) including stump height.												
	10.15[1]	18.3	26.45	34.6	42.75	50.9	59.05	67.2	75.35	83.5	91.65	99.8	107.95
	Diameter inside bark (inches).												
	80-foot trees.												
6	5.3	5.0	4.9	4.7	4.5	4.2	3.7	2.6	......	......	......	......	......
7	6.2	5.9	5.6	5.5	5.1	4.7	4.1	2.9	......	......	......	......	......
8	7.1	6.7	6.4	6.1	5.7	5.3	4.6	3.3	......	......	......	......	......
9	8.0	7.5	7.2	6.9	6.3	5.8	5.0	3.6	......	......	......	......	......
10	8.9	8.3	7.9	7.5	7.1	6.5	5.5	4.0	......	......	......	......	......
11	9.7	9.2	8.7	8.2	7.7	7.0	5.9	4.3	......	......	......	......	......
12	10.7	10.0	9.5	8.9	8.3	7.6	6.4	4.6	......	......	......	......	......
13	11.5	10.9	10.3	9.7	8.9	8.1	6.7	4.9	......	......	......	......	......
14	12.4	11.6	11.0	10.3	9.6	8.7	7.2	5.2	......	......	......	......	......
15	13.3	12.5	11.9	11.1	10.3	9.3	7.7	5.6	......	......	......	......	......
16	14.2	13.4	12.6	11.8	10.9	9.9	8.1	5.9	......	......	......	......	......
17	15.1	14.2	13.4	12.6	11.7	10.4	8.6	6.2	......	......	......	......	......
18	16.0	15.1	14.2	13.3	12.3	11.0	9.1	6.5	......	......	......	......	......
19	16.9	15.9	15.1	14.1	13.0	11.6	9.5	6.7	......	......	......	......	......
20	17.8	16.7	15.9	14.9	13.7	12.2	9.9	7.0	......	......	......	......	......
21	18.7	17.5	16.6	15.6	14.4	12.7	10.3	7.3	......	......	......	......	......
22	19.6	18.4	17.4	16.3	15.0	13.3	10.8	7.6	......	......	......	......	......
23	20.5	19.2	18.2	17.1	15.7	13.9	11.2	7.9	......	......	......	......	......
24	21.3	20.0	19.1	17.9	16.4	14.5	11.7	8.1	......	......	......	......	......
25	22.2	20.9	19.8	18.7	17.2	15.1	12.1	8.4	......	......	......	......	......
26	23.0	21.7	20.6	19.3	17.7	15.7	12.5	8.7	......	......	......	......	......
27	23.9	22.5	21.5	20.2	18.5	16.3	13.0	9.0	......	......	......	......	......
28	24.7	23.5	22.3	20.9	19.2	16.9	13.5	9.2	......	......	......	......	......
29	25.6	24.3	23.1	21.8	19.9	17.5	13.9	9.5	......	......	......	......	......
30	26.5	25.1	24.0	22.5	20.6	18.1	14.4	9.8	......	......	......	......	......
	90-foot trees.												
6	5.4	5.1	5.0	4.8	4.6	4.3	4.0	3.5	2.8	1.5	......	......	......
7	6.2	6.0	5.8	5.5	5.2	4.9	4.6	4.0	3.1	1.6	......	......	......
8	7.2	6.9	6.7	6.3	5.9	5.5	5.2	4.5	3.5	1.8	......	......	......
9	8.0	7.7	7.4	7.1	6.6	6.3	5.8	5.0	3.8	1.9	......	......	......
10	8.9	8.5	8.3	7.8	7.3	6.9	6.3	5.4	4.1	2.1	......	......	......
11	9.8	9.3	8.9	8.5	8.0	7.5	6.9	5.9	4.5	2.3	......	......	......
12	10.7	10.2	9.8	9.3	8.7	8.2	7.5	6.4	4.8	2.4	......	......	......
13	11.6	11.0	10.6	10.1	9.5	8.8	8.1	6.9	5.1	2.6	......	......	......
14	12.5	11.9	11.3	10.8	10.2	9.5	8.7	7.3	5.5	2.7	......	......	......
15	13.4	12.7	12.1	11.5	10.9	10.2	9.2	7.8	5.8	2.9	......	......	......
16	14.3	13.5	12.9	12.3	11.6	10.8	9.7	8.2	6.1	3.0	......	......	......
17	15.1	14.3	13.7	13.0	12.4	11.5	10.3	8.7	6.4	3.2	......	......	......
18	16.1	15.2	14.5	13.8	13.1	12.2	10.9	9.1	6.7	3.3	......	......	......
19	16.9	16.0	15.2	14.5	13.8	12.9	11.5	9.6	7.0	3.5	......	......	......
20	17.9	16.9	16.1	15.3	14.6	13.5	12.1	10.1	3.6	3.6	......	......	......
21	18.7	17.7	16.8	16.1	15.3	14.2	12.6	10.5	7.7	3.8	......	......	......
22	19.7	18.5	17.6	16.9	16.1	14.9	13.2	10.9	8.0	3.9	......	......	......
23	20.5	19.4	18.4	17.6	16.8	15.5	13.7	11.4	8.3	4.1	......	......	......
24	21.5	20.2	19.2	18.4	17.6	16.3	14.3	11.8	8.6	4.3	......	......	......
25	22.3	21.0	20.0	19.2	18.3	16.9	14.9	12.2	8.9	4.4	......	......	......
26	23.2	21.8	20.8	19.9	19.1	17.7	15.4	12.6	9.2	4.6	......	......	......
27	24.0	22.7	21.6	20.7	19.8	18.3	15.9	13.0	9.5	4.7	......	......	......
28	24.8	23.4	22.4	21.5	20.6	19.0	16.5	13.5	9.9	4.9	......	......	......
29	25.7	24.2	23.2	22.3	21.3	19.6	17.1	14.0	10.2	5.1	......	......	......
30	26.5	25.0	24.0	23.1	22.0	20.3	17.5	14.4	10.5	5.3	......	......	......
31	27.4	25.8	24.8	23.9	22.7	20.9	18.2	14.8	10.8	5.4	......	......	......
32	28.3	26.5	25.5	24.7	23.5	21.5	18.6	15.2	11.1	5.6	......	......	......
33	29.1	27.3	26.4	25.5	24.2	22.2	19.3	15.7	11.5	5.8	......	......	......
34	30.0	28.1	27.2	26.3	25.0	22.8	19.8	16.2	11.8	6.0	......	......	......
	100-foot trees.												
8	7.3	7.1	6.8	6.5	6.0	5.6	5.3	5.0	4.4	3.3	1.9	......	......
9	8.2	8.0	7.6	7.3	6.8	6.3	5.9	5.5	4.8	3.7	2.0	......	......
10	9.1	8.8	8.4	8.0	7.5	7.0	6.5	6.1	5.3	3.9	2.2	......	......
11	10.0	9.7	9.2	8.8	8.3	7.7	7.2	6.6	5.7	4.2	2.4	......	......
12	10.9	10.5	10.0	9.5	9.0	8.5	7.8	7.1	6.2	4.6	2.5	......	......
13	11.7	11.3	10.8	10.3	9.7	9.1	8.5	7.7	6.6	4.9	2.7	......	......

[1] The stump height is 2 feet.

TABLE 25.—*Diameter inside bark of Norway pine logs at intervals of 8.15 feet, on the basis of diameter, classed by trees of different heights*—Continued.

Diameter breast-high (inches).	Merchantable length (feet) including stump height												
	10.15[1]	18.3	26.45	34.6	42.75	50.9	59.05	67.2	75.35	83.5	91.65	99.8	107.95
	Diameter inside bark (inches).												
	100-foot trees—continued.												
14	12.6	12.0	11.5	11.0	10.5	9.9	9.1	8.3	7.0	5.1	2.9	......	......
15	13.5	12.9	12.3	11.7	11.2	10.6	9.7	8.8	7.5	5.4	3.0	......	......
16	14.4	13.7	13.1	12.5	12.0	11.3	10.4	9.3	7.8	5.7	3.2	......	......
17	15.2	14.5	13.8	13.2	12.7	12.0	11.1	9.8	8.3	6.0	3.3	......	......
18	16.1	15.4	14.6	14.0	13.5	12.7	11.7	10.4	8.7	6.3	3.4	......	......
19	17.0	16.1	15.4	14.8	14.2	13.4	12.3	10.9	9.1	6.6	3.6	......	......
20	17.9	17.0	16.1	15.5	15.0	14.2	13.0	11.5	9.5	6.9	3.8	......	......
21	18.8	17.8	16.9	16.3	15.7	14.9	13.7	12.0	10.0	7.2	3.9	......	......
22	19.7	18.6	17.7	17.1	16.5	15.6	14.3	12.6	10.4	7.5	4.1	......	......
23	20.6	19.4	18.5	17.9	17.3	16.3	14.9	13.2	10.9	7.9	4.2	......	......
24	21.5	20.2	19.3	18.7	18.0	17.1	15.6	13.7	11.4	8.2	4.4	......	......
25	22.3	21.1	20.1	19.5	18.9	17.8	16.2	14.3	11.9	8.5	4.5	......	......
26	23.3	21.9	20.9	20.3	19.6	18.5	16.9	14.9	12.3	8.8	4.8	......	......
27	24.1	22.7	21.7	21.1	20.4	19.3	17.6	15.5	12.8	9.2	4.9	......	......
28	25.0	23.5	22.5	21.9	21.1	20.0	18.2	16.0	13.3	9.5	5.1	......	......
29	25.9	24.3	23.3	22.6	21.9	20.7	18.8	16.6	13.7	9.9	5.3	......	......
30	26.7	25.1	24.1	23.5	22.6	21.3	19.5	17.2	14.1	10.2	5.5	......	......
31	27.6	26.0	24.9	24.1	23.3	22.0	20.1	17.7	14.7	10.6	5.7	......	......
32	28.5	26.7	25.7	25.0	24.1	22.8	20.6	18.2	15.1	10.8	5.9	......	......
33	29.3	27.5	26.6	25.8	24.8	23.4	21.3	18.7	15.5	11.2	6.0	......	......
34	30.2	28.3	27.4	26.5	25.5	24.0	21.9	19.3	15.9	11.5	6.3	......	......
	110-foot trees.												
12	11.0	10.5	10.0	9.5	9.1	8.5	7.8	7.1	6.3	5.1	3.7	2.1	......
13	11.8	11.3	10.7	10.2	9.8	9.2	8.5	7.7	6.8	5.5	4.0	2.3	......
14	12.7	12.1	11.5	11.1	10.6	10.0	9.3	8.3	7.3	6.0	4.4	2.5	......
15	13.5	12.9	12.3	11.7	11.3	10.7	9.9	9.0	7.8	6.4	4.7	2.7	......
16	14.5	13.7	13.1	12.5	12.1	11.5	10.7	9.6	8.5	6.9	5.1	2.9	......
17	15.3	14.4	13.8	13.3	12.8	12.1	11.3	10.2	8.9	7.3	5.3	3.1	......
18	16.2	15.3	14.6	14.1	13.6	13.0	12.1	10.9	9.6	7.8	5.7	3.3	......
19	17.1	16.1	15.3	14.7	14.3	13.7	12.7	11.5	10.1	8.2	6.1	3.5	......
20	17.9	16.9	16.1	15.6	15.1	14.5	13.5	12.3	10.7	8.7	6.4	3.7	......
21	18.8	17.7	17.0	16.4	15.9	15.1	14.1	12.8	11.2	9.1	6.7	3.9	......
22	19.7	18.6	17.7	17.2	16.7	15.9	14.9	13.6	11.8	9.6	7.1	4.1	......
23	20.6	19.4	18.6	18.0	17.5	16.7	15.6	14.2	12.4	10.1	7.4	4.3	......
24	21.5	20.3	19.4	18.8	18.3	17.4	16.3	14.9	13.0	10.6	7.8	4.4	......
25	22.4	21.1	20.2	19.5	19.0	18.1	16.9	15.5	13.5	11.0	8.1	4.6	......
26	23.3	21.9	21.0	20.4	19.8	18.9	17.7	16.2	14.1	11.6	8.5	4.9	......
27	24.2	22.7	21.9	21.2	20.6	19.7	18.4	16.8	14.7	12.0	8.8	5.1	......
28	25.1	23.5	22.6	22.0	21.4	20.5	19.1	17.5	15.3	12.5	9.2	5.3	......
29	26.0	24.5	23.5	22.7	22.1	21.2	19.9	18.1	15.9	13.0	9.6	5.5	......
30	26.9	25.3	24.2	23.6	23.0	22.0	20.6	18.8	16.4	13.5	10.0	5.7	......
31	27.8	26.1	25.1	24.4	23.7	22.8	21.3	19.5	17.1	14.0	10.4	6.0	......
32	28.7	26.9	25.8	25.1	24.5	23.6	22.1	20.1	17.6	14.5	10.7	6.1	......
33	29.7	27.7	26.7	26.0	25.3	24.3	22.7	20.8	18.2	15.0	11.1	6.5	......
34	30.6	28.5	27.5	26.8	26.2	25.1	23.5	21.4	18.8	15.5	11.5	6.6	......
	120-foot trees.												
16	14.3	13.6	12.9	12.3	11.8	11.2	10.6	9.7	8.7	7.5	6.0	4.3	2.6
17	15.3	14.4	13.8	13.1	12.6	12.1	11.4	10.5	9.4	8.2	6.5	4.7	2.9
18	16.2	15.3	14.6	14.0	13.4	12.8	12.1	11.1	10.0	8.6	7.0	5.2	3.2
19	17.1	16.1	15.4	14.8	14.3	13.6	12.9	11.9	10.6	9.2	7.6	5.6	3.5
20	18.0	16.9	16.2	15.6	15.0	14.4	13.7	12.6	11.3	9.8	8.1	6.0	3.8
21	18.9	17.8	17.0	16.4	15.9	15.2	14.4	13.3	12.0	10.4	8.6	6.4	4.1
22	19.8	18.7	17.8	17.3	16.7	16.0	15.2	14.0	12.6	11.0	9.1	6.8	4.4
23	20.7	19.5	18.6	18.1	17.5	16.8	15.9	14.8	13.3	11.6	9.6	7.2	4.7
24	21.6	20.4	19.4	18.9	18.4	17.6	16.7	15.4	13.9	12.1	10.1	7.7	4.9
25	22.5	21.2	20.3	19.7	19.2	18.5	17.4	16.1	14.6	12.8	10.7	8.1	5.3
26	23.5	22.0	21.1	20.5	20.0	19.2	18.2	16.9	15.2	13.4	11.1	8.5	5.5
27	24.3	22.9	21.9	21.3	20.8	20.1	19.0	17.7	15.9	13.9	11.7	8.9	5.8
28	25.3	23.7	22.8	22.1	21.6	20.9	19.8	18.3	16.5	14.5	12.2	9.2	5.9
29	26.2	24.6	23.6	23.0	22.5	21.7	20.5	19.1	17.3	15.1	12.7	9.7	6.2
30	27.1	25.5	24.4	23.8	23.3	22.5	21.4	19.8	17.9	15.7	13.2	10.1	6.5
31	28.0	26.3	25.3	24.6	24.1	23.4	22.1	20.6	18.7	16.3	13.7	10.5	6.9
32	28.9	27.2	26.1	25.4	24.9	24.1	22.9	21.4	19.3	16.9	14.2	11.0	7.2
33	29.8	28.0	26.9	26.2	25.7	24.9	23.7	22.2	20.0	17.5	14.8	11.4	7.4
34	30.7	28.9	27.8	27.1	26.6	25.8	24.6	22.9	20.7	18.2	15.3	11.8	7.7

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[1] The stump height is 2 feet.

To construct a volume table from the upper diameters or tapers given in Table 25, the average top diameter to which trees are utilized must be known. In species possessing a regular form this may be a fixed limit, as 6 inches, regardless of the size of the tree. But where utilization is not close, and tops are heavy, with large limbs, the diameter limit in the top will increase with the diameter of the tree. With this top diameter determined, the taper table will indicate the merchantable length for each diameter and height class to the nearest 8-foot length. For board feet, adapting a 16-foot log, the upper diameters of each log in the tree enable one to secure the scaled contents by the desired log rule.

The number of standard railroad ties or products of other known dimensions may also be found for trees of any size from this table.

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